GSFC 427-XX-XX-XX

DRAFT

LANDSAT DATA CONTINUITY MISSION

OPERATIONAL LAND IMAGER (OLI)

SPECIFICATION

September 24, 2004

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

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LDCM PROJECT
DOCUMENT CHANGE RECORD

Sheet: 1 of 1

REV LEVEL	DESCRIPTION OF CHANGE	APPROVED BY	DATE APPROVED
Draft June 10, 2004	RFI release.		
Draft September 24, 2004	Updates to RFI release.		

Table of TBDs / TBRs / TBSs

Section	Type	Description

The term "To Be Determined" (TBD) applied to a missing requirement means that the contractor should determine the missing requirement in coordination with the Government. The term "To Be Supplied" (TBS) means that the Government will supply the missing information in the course of this contract. The term "To Be Reviewed" (TBR) means that the requirement is subject to review for appropriateness by the contractor or the Government, with approval by the Government. The Government may change TBR requirements in the course of this contract.

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1.0 INTRODUCTION

1.1 IDENTIFICATION

This Specification sets forth the requirements for the Operational Land Imager, henceforth identified as OLI, for the Landsat Data Continuity Mission.

1.2 MISSION OVERVIEW ASSUMPTIONS

The OLI provides Landsat multispectral image acquisition, storage and playback compatible with the National Polar Operational Environmental Satellite System (NPOESS). The inherent goal of the OLI is to serve as a "standard Operational Land Imager" which will be integrated on the NPOESS Operational Spacecraft (2130 Configuration) and possibly other Landsat/NPOESS gap-filler or bridge missions.

OLI will be required to operate nominally on these platforms to acquire multispectral scenes (177km x 170km) on a 17 day repetitive basis at the NPOESS 2130 ascending node orbit of 828km. ~~Launch date is currently expected in the 2009 timeframe.~~

1.3 ACRONYMS AND DEFINITIONS

Operational Land Imager – The end item deliverable of this contract which includes a Reflective Band Sensor (RBS) and a Data Storage and Playback Subsystem (DSAP).

Reflective Band Sensor (RBS) – The core Landsat multispectral sensing instrument for reflective spectral bands in the visible, near infrared and shortwave infrared

Data Storage and Playback Subsystem (DSAP) – Provides temporary on-board storage and rate buffering of RBS image data

All other definitions and acronyms referenced in this document can be found in the OLI Acronym List and Lexicon.

1.4 STANDARDS

The latest revisions of the following standards apply to this specification.

ASTM E-595	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
ASTM-E1559	Standard Test Method for Contamination Outgassing Characteristics of Spacecraft Materials
CCSDS-101.0-B	Telemetry Channel Coding

CCSDS-301.0-B	Time Code Formats
CCSDS-701.0-B	Advanced Orbiting Systems - Networks and Data Links: Architectural Specification
IEST-STD-CC1246D	Product Cleanliness Levels and Contamination Control Program
ISO 14644-1	Cleanrooms and associated controlled environments -- Part 1: Classification of air cleanliness
ISO 14644-2	Cleanrooms and associated controlled environments -- Part 2: Specifications for testing and monitoring to prove continued compliance with ISO 14644-1
MIL-STD-461	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-882	Standard Practice for System Safety
MIL-STD-1541	Electromagnetic Compatibility Requirements for Space Systems
MIL-STD-1542	Electromagnetic Compatibility and Grounding Requirements for Space Systems Facilities (November 1991)
MIL-STD-1553	Digital Time Division Command/Response Multiplex Date Bus
MIL-STD-2401	Department of Defense World Geodetic System (WGS)
NIMA TR-8350.2	DOD World Geodetic System

1.5 APPLICABLE DOCUMENTS

The Contractor shall comply with the following documents:

Operational Land Imager Statement of Work: Document number TBS

Operational Land Imager Special Test Requirements: Document number TBS

Operational Land Imager Contract Data Requirements List: Document number TBS

Operational Land Imager Mission Assurance Requirements: Document Number TBS

Operational Land Imager Acronym List and Lexicon: Document Number TBS

Top of Atmosphere Radiance Values, MODTRAN 4 Model. http://ldcm.nasa.gov/... TBS

Landsat 7 Worldwide Reference System-3 (WRS-3): TBD – see section 3 for conceptual definition

NIST 2000 realization of scale of spectral irradiance, H. W. Yoon, C. E. Gibson and P. Y. Barnes, The realization of the NIST detector-based spectral irradiance scale, Metrologia 40 (2003) S172–S176.

NPOESS General Instrument Interface Document (GIID), Rev. A, 3 October 2003, NGST Doc. No. 31418

NPOESS 1553 Interface Requirements Document, 31 October 2003, NGST Doc. No. 34470

1.6 REFERENCE DOCUMENTS

NPOESS Space Segment Specification, Rev. D, 01 August 2002, NGST Doc. No. SY26-0009

NPOESS Command, Control, and Communications Segment Specification, NGST Doc. No. SY12-0023

NPOESS Operations Concept, Rev. G, 6 October 2003, NGST Doc. No. 31400

NPOESS Concept of Operations, Rev. G, 28 May 2002, NGST Doc. No. D34635

NPOESS System Specification, Rev. F, 20 August 2003, NGST Doc. No. SY15-0007

NPOESS System Specification, Appendix B, Rev. A, 11 February 2004, NGST Doc. No. SY15-0007-01

NPOESS External IRD/ICDs, NGST Doc. No. D31410

MIL-A-83577B - Assemblies, Moving Mechanical, for Space and Launch Vehicles, General Specification for (February 1988)

PPL-21 - Preferred Parts List, Goddard Space Flight Center (updated May 1996)

MIL-HDBK-1547A - Electronic Parts, Materials, and Processes for Space and Launch Vehicles (6 July 1998)

MIL-HDBK-263B - Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices) (Metric) (31 July 1994)

1.7 DOCUMENT ORGANIZATION

Section 1 is an introduction to this document. Section 2 provides a brief OLI functional overview and operations concept. Section 3 is reserved~~provides the specific interface and operational constraints with respect to hosting OLI on the NPOESS operational spacecraft~~. Section 4 defines the spatial, spectral, and radiometric requirements for imagery acquired by the Reflective Band Sensor to be consistent with the Landsat heritage. Section 5 defines the Data Storage and Playback (DSAP) Subsystem requirements for providing temporary storage and playback of acquired Landsat Imagery. Section 6 defines the OLI Simulator and Ground Support Equipment requirements. Section 7 defines the OLI processor, software and command and data handling requirements.

This document contains all the functional and performance requirements for the OLI, including unique interface requirements to enable OLI to be compatible with the NPOESS operational spacecraft (2130 configuration) and any required Landsat gap-filler or bridge mission requirements.

2.0 OLI FUNCTIONAL OVERVIEW AND OPERATIONS CONCEPT

This section of the OLI Specification provides a functional overview and operations concept for the OLI. As such, the information in this section provides context for the function, performance, and operations of the OLI. The detailed and binding OLI functional and performance requirements are found in Sections 3, 4, 5, 6 and 7 of this document.

2.1 OLI FUNCTIONAL DESCRIPTION

The OLI is required to provide Landsat multispectral image acquisition, storage and playback onboard the operational NPOESS spacecraft or bridge missions for a period of 7 years within the prescribed requirements (see Section 3.5.2). The OLI consists of the major functional subsystems as depicted in Figure 2-1. The Reflective Band Sensor provides VNIR/SWIR imagery consistent with Landsat spectral, spatial, radiometric and geometric qualities as specified in Section 4 of this document. The Data Storage and Playback (DSAP) subsystem provides image data storage and playback from the RBS which is required to meet the Landsat temporal, imaging capacity, and image reconstruction requirements per Section 5 of this document.

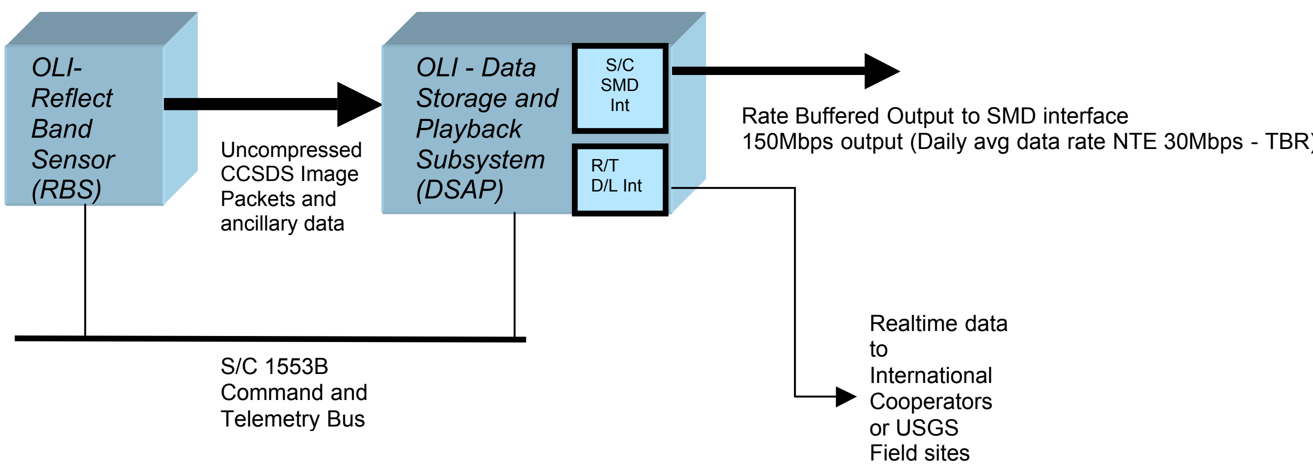


Figure 2-1. OLI with DSAP Functional Block Diagram

2.2 OLI FUNCTIONAL ELEMENTS

Key Functional, Performance and Interface Requirement Overview

The OLI functional elements consist of the RBS and DSAP. The RBS sensor will be mounted on the NPOESS observatory nadir deck (see Figure 2-2). The NPOESS operational spacecraft provides the mechanical, power, thermal and data interfaces as well as the transfer of collected OLI data to the NPOESS stored mission data Ka-band transmitter.

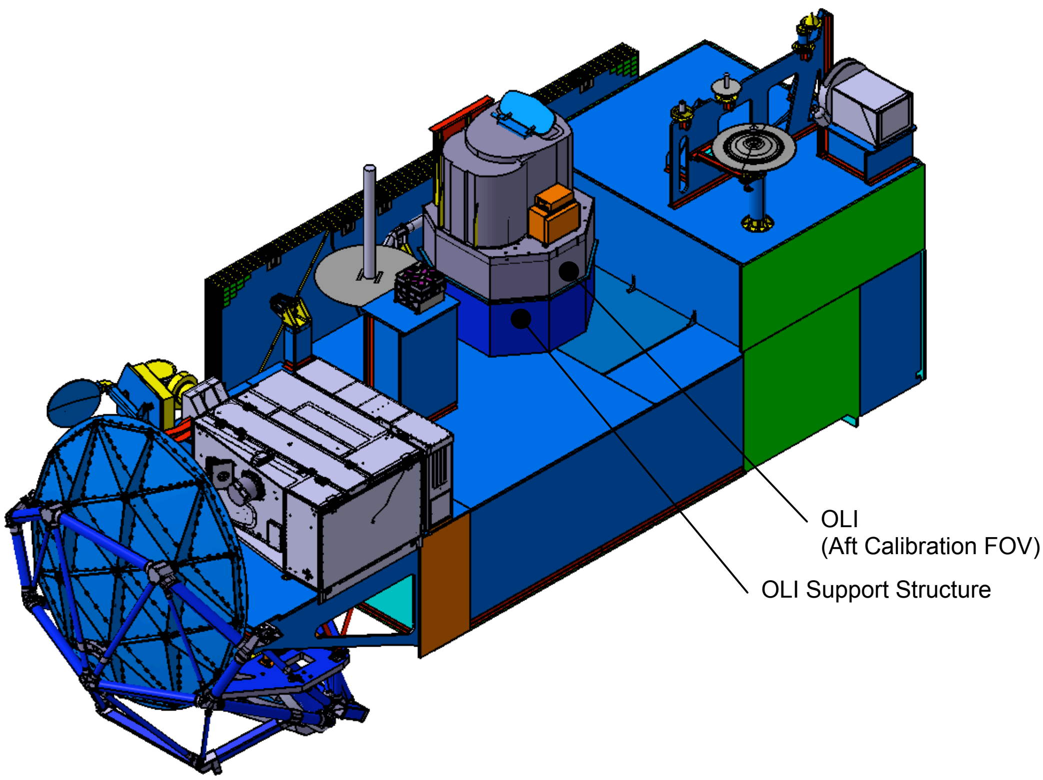


Figure 2-2. OLI on NPOESS 2130 Spacecraft

The currently negotiated OLI envelope of not-to-exceed mass / volume / power/data rate requirements for the OLI on the NPOESS 2130 Spacecraft are shown in Table 2-1.

Table 2-1. OLI Mass / Volume / Power Requirements

	Mass	Volume	Average Orbital Power	Data Rate / Volume
Reflective Band Sensor	200 kg	1.2x x 1.2y x 1.2z m (TBR)	200 W (TBR)	N/A
DSAP	50 kg	0.5x x 0.5y x 0.3z m (TBR)	150 W (TBR)	NTE 30Mbps compressed (TBR) daily average data rate downlinked via the NPOESS SMD interface
OLI Total	250 kg	N/A	350 W (TBR)	400 WRS-3 scenes including ancillary data /day

2.2.1 Description and Tables of Key RBS Capabilities

The RBS includes the optical telescope, Focal Plane Array / Focal Plane Electronics (FPA/FPE) and instrument control electronics. The optical telescope includes the optical bench assembly, baffles and mirrors to gather and focus the optical beam onto the FPA. The FPA/FPE converts photon energy into electrical voltage signals and converts the voltage signals into digital signals. The RBS is specified to provide nine spectral bands with a maximum ground sampling distance, both in-track and cross track, of 30m for all bands except the panchromatic band which is specified to have a 10m ground sampling distance. The 12.55 degree FOV provides the RBS with a 177km cross track swath width at the mission nominal NPOESS orbit of 828 +/- 12 km altitude and 98.7 +/- .05° inclination sun synchronous orbit. The RBS provides both internal calibration sources such as lamps to ensure radiometric accuracy as well as capabilities to perform solar calibrations within the field of view constraints.

Table 2-2. RBS Key Interface Requirements

Parameter	Value
Maximum Mass	200 kg
Maximum Volume	1.2m (x) x 1.2m (y) x 1.2m(z) (TBR)
Max Orbital Average Power	200W (TBR)
Reliability	0.90 (TBR) at 7 years

Table 2-3. RBS Key Operational Requirements

Parameter	Value
Operational Lifetime	7 years
Calibration Sources	Internal, Solar
Command and Control I/F	MIL-STD-1553B
Instrument FOV	Min 12.55deg (177km) cross track

Table 2-4. RBS Key Performance Requirements

#	Band	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)	Maximum GSD*	Edge Slope	SNR @ $L_{Typical}$	SNR @ L_{High}
1	Coastal Aerosol	433	453	30 m	.027 / m	130	290
2	Blue	450	515	30 m	.027 / m	130	360
3	Green	525	600	30 m	.027 / m	100	390
4	Red	630	680	30 m	.027 / m	90	340
5	NIR	845	885	30 m	.027 / m	90	460
6	SWIR 1	1560	1660	30 m	.027 / m	100	540
7	SWIR 2	2100	2300	30 m	.027 / m	100	510
8	Panchromatic	500	680	10 m	.081 / m	80	230
9	Cirrus	1360	1390	30 m	.027 / m	50	N/A

2.2.2 Description and Table of Key DSAP capabilities

The Data Storage and Playback Subsystem (DSAP) provides all of the functions necessary to store, compress and encrypt (if necessary) digital image data from the FPA/FPE of the OLI. The DSAP provides the capacity to ingest a high rate data stream from the RBS and temporarily store up to 150 multispectral scenes (WRS-3) of image and ancillary data (at mission EOL) before this data must be overwritten or deleted. The DSAP on a daily basis will store and transfer for downlink up to 400 multispectral scenes. The NPOESS Ka band Stored Mission Data link will transmit the data to the NPOESS ground system (Safetynet). The DSAP also receives ancillary data from the RBS sensor and spacecraft bus. Ancillary data includes spacecraft attitude, navigation, timing data and key telemetry values from the sensor and spacecraft. OLI ancillary data packets are periodically inserted into the image data stream to provide all necessary image reconstruction information for later ground processing.

The DSAP is assumed to be an onboard ~~independently controlled data storage~~ device that can simultaneously store, process and output the RBS data stream. Mechanically, the DSAP is separate from the RBS and mounted inside the spacecraft bus to maintain thermal isolation from the RBS. For storage of image data the DSAP is expected to ingest data in uncompressed CCSDS image and ancillary data packets and store data either in that form or in compressed form (lossless). The DSAP is expected to provide any necessary error detection and correction to the stored image data to prevent degradation due to Single Event Upsets (SEU's) or other space environmental factors. The DSAP will also~~is also expected to~~ organize and store image into files and correlate any necessary image reconstruction information (ancillary data) based on image receipt time. The DSAP provides the ability~~also is required~~ to concurrently store and playback data as necessary to meet the LDCM data collection and downlink requirements~~operations concept~~. Playback of data is required to allow for priority selection of image files by ground command and must be at a sufficient rate to allow full downlink of all stored data within the allocated Safetynet ground station contacts each day. Additionally, the DSAP is required to provide self-test modes to exercise all internal data paths~~without having to be physically connected to the RBS~~.

Table 2-5. DSAP Key Interface Envelopes and Performance

Parameter	Value
Maximum Mass	50 kg
Maximum Volume	0.5m width x 0.5m length x 0.3m height (TBR)
Standby Power (max)	125 W (TBR)
Max Orbital Average Power	250 W (TBR)
Max Capacity	150 scenes (lossless compression) ~ 0.8-1.6 Tbits
SMD Wideband I/F Output Rate	150Mbps / 300Mbps (rate1/2 Conv Enc)
IC Wideband I/F Output Rate	300 Mbps
Reliability	0.90 (TBR) at 7yrs
Data Storage BER	<1x10E-12
Lifetime	7 years
Control I/F	MIL-STD-1553b

~~2.3OLI OPERATIONS CONCEPT ON NPOESS~~

~~The OLI sensor will fly on the 2130 ascending node NPOESS spacecraft in a near circular frozen orbit of 828km +/- 12km at a 98.7 +/- .05° inclination. The OLI sensor will acquire WRS-3 (TBD) multi-spectral scenes (e.g. 177km cross track x 170km along track) on a 17 day repetitive basis. Nominal OLI imaging operations will begin when the WRS-3 orbit has been achieved and spacecraft and OLI on-orbit checkout and validation has been completed (est. 90-120days). The OLI is expected to operate within the specification set for a nominal period of seven years after on-orbit checkout has been completed.~~

~~A Long Term Acquisition Plan (LTAP) will be developed and maintained by the USGS. The LTAP will provide a methodology for collecting global Landsat imagery based on scientific requirements. Its objective is to maintain an archive of global Landsat data. These requirements and objectives are used to develop a schedule that determines which scenes are collected on a daily basis. The scenes specified by the LTAP are adjusted based on many considerations. These considerations include, but are not limited to: high-priority requests, attempts to recover missed acquisitions, and cloud cover predictions from the National Center for Environmental Prediction (NCEP).~~

~~The OLI Instrument Mission Management Center (MMC) is operated by the USGS and is responsible for command and control of the OLI. It is from here that the list of scenes specified by the LTAP is combined with the International Cooperator (IC) image requests to generate a candidate imaging command load. The command load is transferred to the NPOESS MMC for validation and subsequent uploading to the spacecraft. The schedule/planning period begins 48 hours prior to the imaging sequence; commands are uploaded the day before (*i.e.*   imaging events for day *n* are planned on day *n-2* and uploaded on day *n-1*). The schedule will be uploaded every 24 hours and will cover 36-48 hours of imaging events to allow for missed command upload opportunity.~~

~~In normal operations, the OLI will simultaneously image and playback collected RBS imagery per an imaging-tasking plan, which is directly related to priorities of the LTAP. Nominally, the RBS will be pointed directly at nadir for image collection. Typically, during a single orbit, the RBS will be imaging for up to 30 (TBR) minutes during the sunlight portion of the orbit and for up to 5 (TBR) minutes of the nighttime portion of the orbit. The OLI will be able to capture and store up to 150 WRS-3 images (about 2 maximum orbits of data) before previously collected data needs to be overwritten or deleted.~~

~~During imaging operations, the OLI may be commanded to play back stored image data to primary NPOESS SafetyNet ground stations, or through direct downlink to USGS ground stations. Typically, the OLI will acquire and store data for high rate transfer to the NPOESS SafetyNet. However, the OLI will also have the capability to transmit real-time or stored imagery, to specific USGS International Ground Stations.~~

~~The OLI will possess significant capabilities for ensuring that acquired image data can be constructed into proper end user products on the ground. For example, for each image collected, OLI will also collect any ancillary data from the spacecraft bus that is needed to generate radiometrically corrected and geolocated images of the ground. To support efficient ground data processing and operations, the OLI will provide the ability to reorganize raw image data from the focal plane electronics into coherent files, which contain correlated ancillary data with band sequential image data. This data is organized into selectable files for later downlink via the SMD or direct downlink interface to the high rate ground stations.~~

~~It is also required that OLI maintain the capability to perform internal radiometric characterization. Onboard calibration sources will be operated periodically to maintain tight radiometric characterization and trending of the OLI image data. It is expected that no calibration maneuvers will be performed by the spacecraft.~~

~~USGS institutional systems will provide archive, search and order, processing and distribution services.~~

~~2.4 INTERNATIONAL COOPERATOR OPERATIONS AND DATA FLOW VIA DIRECT DOWNLINK (IF APPLICABLE)~~

~~Requests for International Cooperator (IC) scene acquisitions will be collected from EDC prior to the start of the planning/scheduling run for the requested scenes (24-48 hours prior to the scheduling run, 36 hours prior to the command upload). Requests from ICs will be organized to determine which station will receive the real-time direct downlink. This includes establishing buffer times (when scenes are lost – not downlinked) due to antenna slewing between stations when different aim-points are used.~~

~~IC requests will be submitted to the scheduler, which will determine the downlink preferences (when the downlink should be active or recorded on the DSAP/SSR). Additional logic will determine those scenes that should be sent to the SafetyNet. The combined commands are forwarded to the NPOESS MMC for uploading. Scenes from the schedule will be added to the LTAP collection management database (of all imaging events).~~

~~A Contact Schedule will be generated by the OLI instrument MMC and sent to the ICs once the candidate schedule has been generated and the command load accepted (validated and scheduled for upload) by the NPOESS MMC (approximately 24 hours before the scheduled imaging event). Current ephemeris will be obtained from the NPOESS MMC and also sent with the contact schedule. ICs will acquire some requested scenes via direct downlink and others from EDC (where they are gathered from the SafetyNet).~~

3.0 RESERVED~~OLI REQUIREMENTS AND INTERFACE CONSTRAINTS~~

~~Prior to release of this RFI/RFP package, NASA-GSFC, USGS, IPO and the NPOESS Contractor (NGST) performed a preliminary accommodation study to determine the feasibility of interfacing a notional OLI RBS sensor and DSAP into the NPOESS space and ground architecture.~~

~~The study conducted was based on an OLI Reflective Band Sensor concept which is based on evolving the EO-1/ALI sensor to a fully populated and fully operational sensor on the NPOESS 2130 Spacecraft. The NPOESS 2130 ascending node spacecraft was chosen as it best matched the current morning orbit crossing time for Landsat to maintain consistency in sun angle view. The NPOESS 2130 will operate in an 828km +/-12km near circular sun synchronous 17 day repeat orbit inclined by 98.7degrees.~~

~~3.1NOTIONAL OLI DESIGN CONCEPT~~

~~The notional OLI RBS design concept discussed is based on an evolved (EO-1/ALI) pushbroom RBS instrument which can operate at the NPOESS orbit and fully meet all requirements for a seven year period. A brief OLI/NPOESS Accommodation Study was also done to scale a previously generated OLI-RBS Sensor concept design into one which could meet the same requirements in the NPOESS orbit.~~

~~The overall OLI notional design assumed the minimum spectral/spatial and radiometric (SNR) requirements (section 4) and, in working the notional design against the current NPOESS design baseline, assumed collection and downlink of up to 400 WRS-3 (see section 3.3) equivalent scenes per day (average constant daily data rate of approx. 30Mbps) via the NPOESS SMD link to SafetyNet.~~

~~The DSAP notional design assumed a commercially available flight qualified SSR capable of simultaneously acquiring, processing and outputting OLI image and ancillary data to the NPOESS Stored Mission Data (SMD) interface. The DSAP was assumed to have approximately 1 Tbit of EOL storage and be capable of ingesting data at the full uncompressed RBS sensor and ancillary data rate (330Mbps(TBR) and playback this data to the 150Mbps SMD interface.~~

~~The results of this NPOESS accommodation study are provided as currently negotiated NPOESS/OLI interface requirements in sections 3.4 – 3.8 based on this notional OLI design concept.~~

~~3.2MAIN REFERENCES~~

~~The key references studied and discussed between the OLI Specification team and NPOESS contractor are the NPOESS System Specification and NPOESS GIID (see Section 1.5). The study team focused primarily on these references to work interface and accommodation issues.~~

~~3.3WRS-3 REFERENCE CONCEPT~~

~~For the OLI on NPOESS accommodation study, the current Landsat WRS-2 (16 day repeat) path/row image acquisition reference system has been evolved into a new 17 day repeat WRS-3 image acquisition reference system. However, the exact ground track and scene center locations have not been fully defined by the Landsat user community at this time. Therefore, for purposes of this specification, the WRS-3 concept is assumed to be similar to the current WRS-2 cycle except that now 241 WRS-3 paths are defined rather than 233 due to the increased revisit period (17 days vs. 16 days). The number of rows (248) can be assumed consistent between the two reference systems as the along track dimension is the same. For purposes of sizing a WRS-3 scene, the OLI specification assumes a 177 km cross track and 170 km along track dimension per scene which includes all cross track data for all spectral bands (i.e. includes any required additional time to avoid gaps due to focal plane sensor chip assembly overlap structure).~~

~~3.4KEY OLI INTERFACE ENVELOPES ON NPOESS~~

~~3.4.1Mass/Power/Volume Envelopes~~

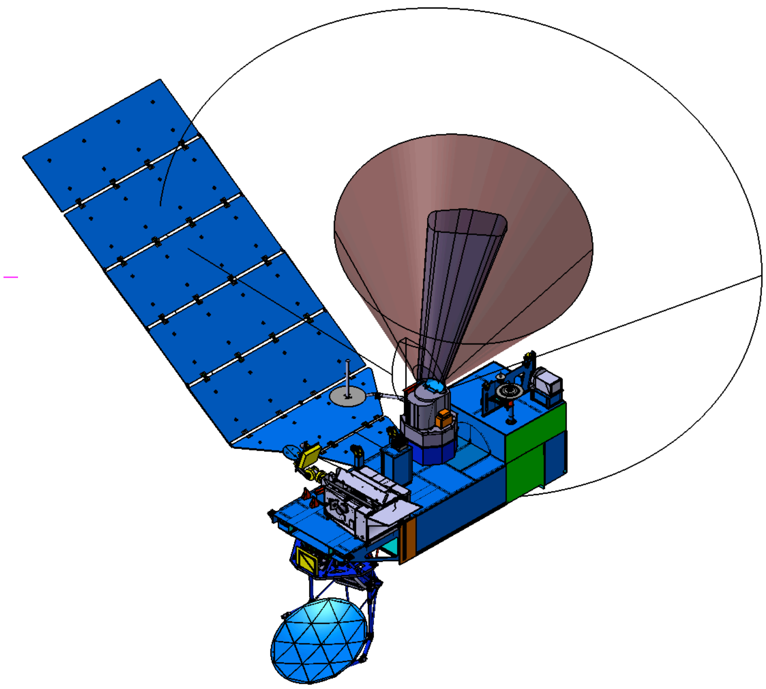
~~Based on the notional OLI Instrument concept the OLI design shall be within the following negotiated not to exceed, mass/ power/volume envelopes for OLI on NPOESS. These interface envelopes shall include all required NPOESS accommodation hardware plus an additional growth margin.~~

~~Table 3-1. OLI Mass / Volume / Power/Data Rate Interface Envelopes~~

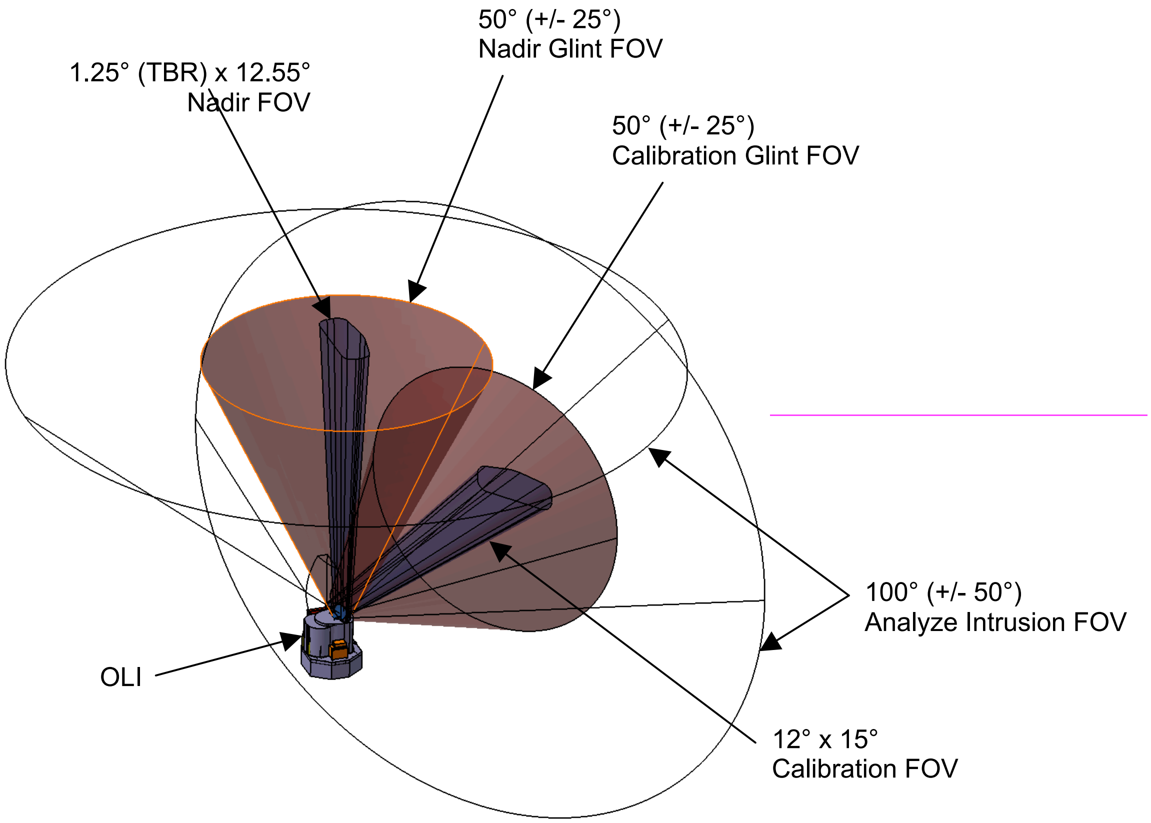
	~~Mass~~	~~Volume~~	~~Average Orbital Power~~	~~Data Rate / Volume~~
~~Reflective Band Sensor~~	~~200 kg~~	~~1.2x x 1.2y x 1.2z m (TBR)~~	~~200 W (TBR)~~	~~N/A~~
~~DSAP~~	~~50 kg~~	~~0.5x x 0.5y x 0.3z m (TBR)~~	~~150 W (TBR)~~	~~NTE 30Mbps compressed (TBR) daily average data rate downlinked via the NPOESS SMD interface~~
~~OLI Total~~	~~250 kg~~	~~N/A~~	~~350 W (TBR)~~	~~400 WRS-3 scenes including ancillary data /day~~

~~3.4.2OLI Field of View Constraints~~

~~The OLI RBS sensor, again based on the notional evolved ALI design, requires both a nadir field of view and solar calibration field of view. Figure 3-1 shows OLI with respect to NPOESS and Figure 3-2 illustrates the OLI field of view geometries derived from the preliminary Government NPOESS/OLI accommodation study..~~



~~Figure 3-1. NPOESS Accommodation of OLI FOVs~~



~~**Figure 3-2. OLI Field of View Geometries**~~

~~3.4.2.1 Nadir Field of View~~

~~The OLI shall be constrained to the following minimal field of view for nominal imaging: 12.55 degrees cross-track x 1.25 (TBR) degrees along track per Figure 3-2.~~

~~3.4.2.2 Solar Calibration Field of View~~

~~The solar diffuser surface shall have a view of the sun unobstructed by spacecraft structures for any time of the year across a range of solar elevation angles from -26° to +10° relative to the local horizontal for either the post eclipse exit portion of the orbit (for a forward facing solar diffuser) or the pre eclipse entrance portion of the orbit (for an aft facing solar diffuser). The sun position is nominally 35° ± 8° in azimuth towards the sun side from the velocity vector or anti-velocity vector, respectively, for the post eclipse exit and pre-eclipse entrance portions of the orbit.~~

~~3.4.3 Command and Telemetry Interfaces~~

~~NPOESS will provide the OLI instrument with a MIL-STD-1553B interface based on NPOESS reference document D34470.~~

3.4.4~~OLI Image and Ancillary Data Interface~~

~~A preliminary data throughput analysis of average daily output data rate (based on data rate for minimum sensor spatial/spectral characteristics) from the OLI indicated that the standard NPOESS sensor 1394 interface was insufficient to acquire, process and downlink the OLI requirement for an average of 400 WRS-3 (177km x 170km) equivalent scenes per day.~~

~~Therefore an OLI – DSAP image data output interface is required to allow for multiplexing of OLI image and ancillary data directly to a separate modulated interface provided by the NPOESS Stored Mission Data interface link (Ka-band) during Safetynet ground receptor site contact times. Nominally, the NPOESS C&DH system will output other NPOESS instrument and ancillary data (i.e. VIIRS, CRIS), then switch for a limited period of time to the OLI data output followed by a resend of the other NPOESS instrument data (to maintain latency rates).~~

3.4.5~~NPOESS 2130 Geodetic Pointing~~

~~The OLI RBS concept sensor design as discussed was based on an evolved EO-1 ALI design which assumed an autonomously yaw-steered spacecraft (i.e. like EO-1) sweeping the detector sensor chip assemblies (SCA's) perpendicular to the ground velocity vector to achieve inherent spectral/spatial registration of the data. However, since the NPOESS spacecraft are geodetically pointed, the heritage OLI-RBS concept design would incur gaps in image data unless sufficient accommodation hardware was provided. The possible accommodation hardware design alternatives are many. For purposes of the notional OLI sensor design, a yaw steering table controlled independently by the OLI instrument, based on ephemeris and attitude data collected periodically from the spacecraft bus, was assumed.~~

~~The OLI-RBS design shall include all accommodation hardware to ensure registration of spatial and spectral data within the RBS image output stream while flying on a non-yaw steered spacecraft.~~

3.4.6~~Observatory Stability~~

~~The jitter profile currently specified in the GIID will not meet OLI imaging stability requirements for the LDCM spectral bands.~~

~~The NPOESS program believes that once final dynamic structural modeling is completed in the Fall of 2004, the final 2130 NPOESS spacecraft jitter profile at the OLI interface will be substantially improved over the current NPOESS GIID-specified jitter spectrum.~~

~~Assuming the current NPOESS GIID jitter profile, a notional method was developed to close the gap between the currently predicted GIID specified jitter profile and the performance required by OLI. Angular displacement sensors located on the OLI RBS and an increase in the telemetry readout of the spacecraft ancillary data (see table 3-2) would allow correction of the data from the remaining jitter spectrum.~~

~~Therefore the OLI shall provide any hardware required to ensure sufficient imaging stability within the current NPOESS GIID jitter profile.~~

~~Additionally, the OLI shall meet the following interface line of sight and maximum allowable jitter on RBS requirements:~~

~~3.4.6.1 Relative Line of Sight Knowledge~~

~~The relative detector lines of sight (line of sight at time t+Δt relative to the line of sight at time t) shall be known to an accuracy of 1 μrad (1-sigma) (TBR) where Δt ≤ 5 seconds, in the spacecraft bus vibration environment specified in the NPOESS GIID, Sections 4.2.7.1 and 4.2.7.2.~~

~~3.4.6.2 Maximum Allowable Jitter on RBS~~

~~Given the input jitter spectrum from the NPOESS GIID, the OLI shall provide the necessary capability to ensure that the total integrated RBS line of sight jitter shall be less than 1 microradian RMS for all frequencies over 50 Hz (TBR) (i.e. sqrt{integral[50.0 Hz, infinity;S(f)^2df]} < 1 microradian where S(f)^2).~~

~~3.5 OLI RELIABILITY REQUIREMENT~~

~~The OLI shall be designed operate for 7 years after initial operations capability and meet a minimum probability of success of 0.8 (TBR) at the end of 7 years.~~

~~3.6 OLI INTERFACE REQUIREMENTS TO MEET THOSE IN NPOESS GIID~~

~~The OLI shall comply with all NPOESS GIID interface requirements (document number D31418, Rev. A) except as noted in section 3.7.~~

~~3.7 OLI INTERFACE REQUIREMENTS IN VARIANCE WITH NPOESS GIID~~

~~This section identifies the OLI interface requirements which, based on the NPOESS accommodation study, are in variance with the requirements specified in the NPOESS GIID (document number D31418, Rev. A). These interface requirements shall be met to ensure that OLI can meet its imaging requirements and be integrated into the current NPOESS 2130 platform.~~

~~3.7.1 OLI - Ancillary Data input from NPOESS Spacecraft~~

~~The OLI shall provide the NPOESS spacecraft (and bridge/gap filler spacecraft if applicable) with ancillary data updates per Table 3-2 to ensure that imaging stability and geolocation accuracies requirements are met.~~

~~Table 3-2. NPOESS Spacecraft Ancillary Data Update Rate and Accuracy for OLI Interface~~

~~Spacecraft Parameter~~	~~Minimum Update Rate~~	~~Accuracy 1 sigma~~	~~Accuracy of time correlation to GPS time, 1 sigma~~
~~Measured attitude with respect to body frame~~	~~5.0Hz~~	~~7 arc-sec~~	~~16 usec~~
~~Individual gyro axis rate data~~	~~32hz~~	~~0.75 arc-sec over 60sec window~~	~~16usecs~~
~~Reaction Wheel measured rates~~	~~1Hz~~	~~+/- 12.5RPM~~	~~10msec~~
~~GPS time, velocity, position, carrier phase and spacecraft id~~	~~1Hz~~	~~30m spherical error probability~~	~~N/Z~~
~~S/C actuators measured position (i.e. solar arrays)~~	~~0.5 Hz~~	~~0.5 degrees~~	~~10msec~~
~~High Gain antenna gimbals measured angles~~	~~1.0Hz~~	~~0.1 degrees~~	~~10msec~~
~~RT Ephemeris Calculation~~	~~1.0 Hz~~	~~10m~~	~~100usec~~
~~Image data collection time stamp~~	~~Per instrument line rate~~	~~N/A~~	~~16usec~~

~~3.7.2 RBS Alignment Uncertainty between S/C Attitude Reference at RBS and Instrument Interface Reference – Absolute~~

~~The OLI design shall ensure that the alignment between the NPOESS spacecraft attitude reference at the RBS interface shall be known to an accuracy of 36 arcsec (1-sigma), or less.~~

~~3.7.3 Alignment Uncertainty between S/C Attitude Reference at the RBS Interface Reference - Stability (over a WRS3 Cycle)~~

~~The OLI design shall ensure that the alignment between the NPOESS spacecraft attitude reference and the RBS instrument interface shall be stable to within 2 arcsec (1-sigma) or less over a period of 17 days.~~

3.7.4 ~~Alignment Uncertainty between S/C Attitude Reference and Instrument Interface Reference - Stability (over a WRS3 Scene)~~

~~The OLI design shall be such that the alignment between the NPOESS/Bridge mission spacecraft attitude reference at the RBS instrument interface shall be stable to within 1 arcsec (1-sigma) or less over a period of 30 seconds.~~

3.8 ~~OLI IMAGE NTE DATA RATE REQUIREMENT VIA SMD LINK~~

~~A preliminary data throughput analysis of average daily output data rate (based on data rate for minimum sensor spatial/spectral characteristics) from the OLI indicated that the standard NPOESS sensor 1394 interface was insufficient to acquire, process and downlink the OLI requirement for an average of 400 WRS-3 (177km x 170km) scenes per day.~~

~~Therefore an OLI image data output interface requires multiplexing of OLI image and ancillary data directly onto a separate modulated interface provided by the NPOESS Stored Mission Data interface link (Ka-band) during Safetynet ground contact times. Nominally for each Safetynet downlink contact, , the NPOESS C&DH system will output other NPOESS instrument and ancillary data (i.e. VIIRS, CRIS), then switch for a limited period of time to the OLI data output followed by a resend or futher output of the other NPOESS instrument data. A model of Safetynet was run with representative OLI data (at 400WRS-3 scenes/day) for a 17day cycle. Based on the results of this model the following not to exceed requirement for image and ancillary data was derived.~~

~~The NPOESS spacecraft SMD interface shall provide the OLI DSAP with a bandwidth equivalent to an average daily continuous rate of 30 Mbps (TBR) to ensure that the OLI can collect and downlink an average of 400 WRS-3 scenes per day.~~

4.0 REFLECTIVE BAND SENSOR (RBS) REQUIREMENTS

4.1 OPERATIONAL, PHYSICAL, MECHANICAL, AND STRUCTURAL REQUIREMENTS

4.1.1 General

The RBS shall be comprised of the sensor module, all associated sensor control electronics and power modules, all required control, signal processing and data formatting electronics, and interface cabling to the DSAP and Spacecraft bus control interface.

4.1.1.1 RBS Modes of Operation

The RBS sensor shall implement the following modes and functionalities, as appropriate and defined herein.

OFF Mode
Activation Mode
Outgas Mode
Early Orbit Checkout
Standby Mode
Operational Mode
Solar Calibration Mode
Internal Source Calibration Mode
Deep Space/Lunar View Mode
Decontamination Mode
Diagnostic Mode
Instrument Safe Mode
Survival Mode

4.1.1.1.1 OFF Mode

4.1.1.1.1.1 Instrument Power

In the Instrument OFF Mode, the instrument shall receive no external power, including survival heater power and operational power.

4.1.1.1.1.2 Sudden Entry into OFF Mode

The instrument shall be capable of withstanding, without damage, the sudden entry into the OFF mode. This refers specifically to the sudden removal of operational power without first going through an orderly shut-down sequence.

Any special sequences required to re-configure from sudden entry into OFF mode, will be documented in the ICD.

Instrument OFF mode may be used for ground storage and transportation, launch, and spacecraft power crisis situations.

4.1.1.1.2 Activation Mode

Activation mode refers to instrument turn-on, and subsequent instrument component warm up, or cool down, to the operating temperatures. Activation mode terminates when all instrument temperatures, biases, and currents have stabilized within specified operational limits. Activation mode also includes any deployments and opening of covers or shutters.

The instrument contractor will define, for documentation in the ICD, what activation sequences / events are required, where they are necessary, and specific spacecraft control requirements, including appropriate algorithms to be implemented.

During power up, the instrument shall enable the command and telemetry functions, and provide for orderly turn-on based on commands to the instrument.

4.1.1.1.3 Outgas Mode

The RBS shall implement an Outgas Mode. Initial outgas will occur during Launch and Early Orbit~~L&EO~~ after the satellite has successfully reached ~~its~~ orbit and the solar array has successfully deployed.

4.1.1.1.3.1 Mode Utilization

This mode shall be utilized to outgas and evaporate contaminants from RBS hardware to prevent contamination from jeopardizing performance.

4.1.1.1.3.2 Health and Status Data

In this mode, health and status data shall be collected and transmitted, but not mission or calibration data.

4.1.1.1.3.3 Decontamination

This mode shall also be exercised at any time during the mission when decontamination is required.

4.1.1.1.4 Early Orbit Checkout Mode

4.1.1.1.4.1 Complete Spacecraft Checkout

Once on-orbit, the Early Orbit Checkout period shall be devoted to a complete spacecraft checkout and the calibration and performance verification of the payload. These performance verification tests may be repeated at appropriate times during the operational phase of the mission. Verification that performance complies with design and meets requirements defines success in this mode.

4.1.1.1.4.2 Early Orbit Checkout and Anomaly Resolution

To support early orbit checkout, and for anomaly resolution, the instrument contractor shall provide the capability to selectively disable any on-orbit processing operation that combines or compresses raw data in any manner.

Examples of such processing operations are: spatial aggregation of pixel samples; temporal aggregation of pixel samples; averaging of pixel data acquired while viewing calibration sources; averaging of calibration instrumentation data such as source temperature measurements; and data compression.

During this mode, the instrument peak data rate must be maintained. The instrument contractor may maintain this data rate within requirements by limiting the portion of the swath or number of bands for which data are transmitted, or by any other means consistent with providing maximum flexibility and utility for performing diagnostics.

4.1.1.1.5 Standby Mode

In the Standby Mode, the RBS shall be in a fully functional configuration without any science data being collected.

The RBS shall be able to transition upon command from Standby Mode to Operational Mode or vice versa within 2 seconds or less (TBR).

4.1.1.1.6 Operational Mode

4.1.1.1.6.1 Definition

In the Operational Mode the instrument shall be fully functional, providing all data needed to satisfy the performance requirements for the instrument.

4.1.1.1.6.2 Necessary Data

This data shall include normal mission data, housekeeping telemetry, and periodic calibration information, as required.

All allocated spacecraft resources will be available to the instrument in this mode.

4.1.1.1.6.3 During Orbit Correction

The instrument shall be capable of remaining in normal operational mode ~~and meeting all performance requirements~~ without damage while the spacecraft performs orbit correction. The instrument is not required to meet performance requirements during orbit correction.

4.1.1.1.7 Calibration Modes

Instrument Calibration Modes may be considered as submodes of the Operational Mode described above.

4.1.1.1.7.1 Solar Calibration Mode

In the Solar Calibration Mode the instrument shall be in an operational configuration and deploy any required devices, such as solar diffusers, and activate any sources or sensors that are required for solar calibration.

4.1.1.1.7.2 Internal Source Calibration Mode

In the Internal Source Calibration Mode the instrument shall be in an operational configuration and deploy any required devices, and activate internal radiometric sources and sensors that are required for internal calibration.

4.1.1.1.7.3 Deep Space/Lunar View Mode

In the Deep Space/Lunar View Mode the instrument shall be in an operational configuration and activate/deactivate~~deploy~~ any devices that may be required for deep space or lunar imaging. This mode only applies if the spacecraft is maneuvered to put deep space or the moon into the Earth FOV of the OLI.~~, and activate sensors that may be required for deep space or lunar viewing.~~

4.1.1.1.8 Decontamination Mode

The RBS shall be configured to periodically evaporate contaminants which may have been deposited on critical optical surfaces. In this mode, health and status data will continue to be collected and transmitted, while mission or calibration data will be excluded. This mode may be functionally the same as the Outgas Mode described above.

4.1.1.1.9 Diagnostic Mode

4.1.1.1.9.1 Updates to Housekeeping Telemetry and Software

The instrument Diagnostic Mode shall support updates to housekeeping telemetry and software.

4.1.1.1.9.2 Troubleshooting

The Diagnostic Mode shall support trouble shooting, by allowing different telemetry sampling rates as documented in the ICD

4.1.1.1.10 Instrument Safe Mode

For instances of an instrument-detected on-orbit failure, where failure to take prompt corrective action could result in damage to the instrument, the instrument shall place itself into a Safe Mode.

4.1.1.1.10.1 Spacecraft Notification

The instrument shall notify the spacecraft that it has placed itself into the Instrument Safe Mode and then await specific further commands via the spacecraft.

4.1.1.1.10.2 Data to be Collected and Transmitted

In this mode, health and status data shall continue to be collected and transmitted, but not mission or calibration data.

4.1.1.1.10.3 Pre-Turnoff

The instrument shall configure itself such that no damage will occur if the next action from the spacecraft is to turn off the instrument. The instrument may, by choice, utilize this mode as an intermediate state between Operational and Off, or Operational and Survival Modes.

4.1.1.1.10.4 Command Receipt

The instrument shall also enter this mode upon receipt of a command from the spacecraft. By example this command could be a forwarded ground command, or generated by the spacecraft in response to a power system anomaly. The instrument may also be commanded to enter Instrument Safe Mode when the Spacecraft is performing scheduled thruster activity, such as for orbit maintenance.

4.1.1.1.10.5 Autonomous Configuration

The instrument shall autonomously configure to its Safe Mode within 45 seconds (TBR) after entry into Safe Mode is initiated.

4.1.1.1.10.6 Inhibition of Autonomous Entry Initiation

Autonomous Instrument Safe Mode entry initiation, by the instrument, shall be inhibitable by command from the spacecraft or by other mechanism documented in the ICD.

4.1.1.1.10.7 Forcing Instrument Safe Mode

The command from the spacecraft for the instrument to enter Instrument Safe Mode (i.e., "forcing" instrument safe mode) shall not be inhibitable by the instrument.

4.1.1.1.10.8 Transition to Other Modes

The instrument shall not autonomously transition from Instrument Safe Mode to any other mode.

4.1.1.1.10.9 Entry into Instrument Safe Mode

The instrument shall enter Instrument Safe Mode upon: a) receipt of a spacecraft command to enter Instrument Safe Mode, ~~or~~ b) failing to receive twelve (12) (TBR) consecutive time code data packets from the spacecraft, or c) deploying protection for direct solar illumination.

4.1.1.1.10.10 Number of Missed time Code Packets

The number of missed time code packets which result in Instrument Safe Mode shall be alterable on-orbit over the range of 8 (TBR) up to a maximum of 63 (TBR) consecutive time code data packets.

4.1.1.1.11 Survival Mode

Survival Mode is entered when a critical power shortage has been identified by the spacecraft. In this low power mode only those functions required for satellite safety, diagnostics and recovery to full operational status, will be powered. All instruments on the spacecraft will be reactivated by ground command upon spacecraft recovery.

4.1.1.1.11.1 Survival Mode Initiation

Initiation of Survival Mode shall not require commands to the instrument.
The spacecraft will place the instrument into Survival Mode in the event of a severe spacecraft emergency. This may be the end state of the SPACECRAFT SAFE mode described above. *The spacecraft will remove instrument operational power during Survival Mode. The spacecraft will ensure instrument survival heater power is enabled during Survival Mode.* Note: if survival heater power consumption threatens survival of the satellite, the spacecraft may turn off the survival heaters. At that point, the instrument is in the Off mode, rather than the Survival Mode.

Instrument survival power will be enabled, only if sufficient power is available.

4.1.1.1.11.2 Sun-Pointing Attitude

In Survival Mode, the instrument shall be able to survive indefinitely while the spacecraft is in a Sun-Pointing Attitude.

Definition of Sun-Pointing Attitude: As part of entry into the Survival Mode, the Spacecraft will transition from an earth-pointing to a sun-pointing attitude. This attitude is achieved when the solar array is positioned normal to the sun and the spacecraft slowly rotates about the sunline at approximately 2 rev/orbit.

In Survival Mode, the spacecraft will be responsible for sampling critical instrument temperatures via the instrument passive analog temperature sensors (normal instrument telemetry is not available with operational power off).

4.1.2 Maximum RBS Volume

Launch Configuration Volume

The RBS shall not exceed a launch configuration volume of 1.2 m (x) width x 1.2 m (y) length x 1.2 m (z) (TBR) height.

Operational ConfigurationVolume

…

Calibration Configuration Volume

…

4.1.3 Maximum RBS Mass

The RBS mass shall not exceed 200kg (TBR) kg total, including all modules, and intra module cable harnesses.

4.1.4 RBS Mechanical interface

4.1.4.1 Mounting Interface

The mounting method of the RBS to the spacecraft shall accommodate manufacturing tolerance, structural, and thermal distortions.

4.1.5 Line of Sight Pointing Knowledge

4.1.5.1 Detectors to Optical Axes

The line of sight (LOS) pointing of each detector in the RBS, relative to the RBS optical axes, shall be known to ≤ 10 µrad (1-sigma) (TBR) at RBS delivery, over the expected zero-G, vacuum and thermal operating conditions.

4.1.5.2 Optical Axes to RBS

The orientation of the RBS optical axes, relative to an external optical alignment reference device on the RBS, shall be known to ≤ 25 µrad (1-sigma) (TBR) at RBS delivery.

4.1.5.3 RBS to Spacecraft Alignment

The external optical alignment device on the RBS shall be located in such a place as to facilitate optical alignment measurement relative to the spacecraft inertial reference unit (IRU) and/or star trackers

4.1.5.4 Optical Axes to RBS Mounting Surface

4.1.5.4.1 Optical Axes to RBS Mounting Surface - Absolute

The orientation of the RBS optical axes relative to the RBS mounting surface in the instrument's nominal nadir-viewing configuration shall be known to ≤ 25 μrad (1-sigma) (TBR) at RBS delivery.

4.1.5.4.2 Optical Axes to RBS Mounting Surface - Relative

Changes in the orientation of the RBS optical axes relative to the RBS mounting surface due to the operation of the instrument (e.g., yaw steering), shall be known to ≤ 5 μrad (1-sigma) (TBR) over all RBS operating conditions.

4.1.6 Line of Sight Stability

4.1.6.1 Line of Sight Jitter Knowledge

The jitter of the RBS optical axes shall be measured to an accuracy ≤ 1 μrad (1-sigma) (TBR) over frequencies from 0.2 Hz (TBR) to 250 Hz (TBR), with the spacecraft bus angular jitter profile specified in section 3.2.4.2.3.3.8 of the NPOESS GIID.

4.1.6.2 Line of Sight Jitter Suppression

Given the input angular jitter and linear acceleration spectra from the NPOESS GIID section 3.2.4.2.3.3.8 and section 3.2.6.3.1, the OLI shall provide the necessary capability to ensure that the total integrated RBS line of sight jitter shall be less than 2 microradians RMS for all frequencies between 50 Hz (TBR) and 2000 Hz (TBR) (i.e. sqrt{integral[50.0 Hz, 2000.0 Hz;S(f)^2df]} < 2 microradians where S(f)^2 is the PSD of the LOS jitter).

4.1.6.3 Stability over Operating Conditions

4.1.6.3.1 Detector Line of Sight Stability over Operating Conditions

The detector lines if sight, relative to the RBS optical axes, shall be stable to ≤ 2 μrad (1-sigma) (TBR) over 17 days, over all operating conditions

4.1.6.3.2 Optical Axes Stability over Operating Conditions

The orientation of the RBS optical axes relative to the RBS mounting surface in the instrument's nominal nadir-viewing configuration shall be stable to ≤ 5 μrad (1-sigma) (TBR) over 17 days, over all operating conditions.

4.1.6.4 Long-Term Drift

4.1.6.4.1 Detector Line of Sight Long-Term Drift

The detector lines if sight, relative to the RBS optical axes, shall be stable to ≤ 5 μrad (1-sigma) (TBR) over one year.

4.1.6.4.2 Optical Axes Long-Term Drift

The orientation of the RBS optical axes relative to the RBS mounting surface in the instrument's nominal nadir-viewing configuration shall be stable to ≤ 10 μrad (1-sigma) (TBR) over one year.

~~4.1.5 Lines of Sight Knowledge~~

~~4.1.5.1 Detectors to Optical Axes~~

~~The line of sight (LOS) of each detector in the RBS, relative to the RBS optical axes, shall be known to ≤ 10 μrad (1-sigma) (TBR) at RBS delivery, over the expected operating conditions.~~

~~4.1.5.2 Optical Axes to RBS~~

~~The orientation of the RBS optical axes, relative to an external optical alignment reference device on the RBS, shall be known to ≤ 25 μrad (1-sigma) (TBR) at RBS delivery.~~

~~4.1.5.3 RBS to Spacecraft Alignment~~

~~The external optical alignment device on the RBS shall be located in such a place as to facilitate optical alignment measurement relative to the spacecraft inertial reference unit (IRU) and/or star trackers~~

~~4.1.5.4 Optical Axes to RBS Mounting Surface~~

~~4.1.5.4.1 Optical Axes to RBS Mounting Surface - Absolute~~

~~The orientation of the RBS optical axes relative to the RBS mounting surface in the instrument's nominal nadir-viewing configuration shall be known to ≤ 25 μrad (1-sigma) (TBR) at RBS delivery.~~

~~4.1.5.4.2 Optical Axes to RBS Mounting Surface - Relative~~

~~Changes in the orientation of the RBS optical axes relative to the RBS mounting surface due to the operation of the instrument (e.g., yaw steering), shall be known to ≤ 5 μrad (1-sigma) (TBR) over all RBS operating conditions.~~

~~4.1.6 Lines of Sight Stability~~

~~4.1.6.1 Line of Sight Jitter~~

~~The total integrated root-mean square (rms) jitter of the RBS optical axes shall be measured to an accuracy ≤ 1 μrad (1-sigma) (TBR) over frequencies from 0.5 Hz (TBR) and above, with the spacecraft bus vibration PSD specified in appendix B.~~

~~4.1.6.2 Stability over Operating Conditions~~

~~4.1.6.2.1 Detector Line of Sight Stability over Operating Conditions~~

~~The detector lines if sight, relative to the RBS optical axes, shall be stable to ≤ 1 μrad (1-sigma) (TBR) over 17 days, over all operating conditions.~~

~~4.1.6.2.2 Optical Axes Stability over Operating Conditions~~

~~The orientation of the RBS optical axes relative to the RBS mounting surface in the instrument's nominal nadir-viewing configuration shall be stable to ≤ 5 μrad (1-sigma) (TBR) over 17 days, over all operating conditions.~~

~~4.1.6.3 Long-Term Drift~~

~~4.1.6.3.1 Detector Line of Sight Long-Term Drift~~

~~The detector lines oif sight, relative to the RBS optical axes, shall be stable to ≤ 5 μrad (1-sigma) (TBR) over one year.~~

~~4.1.6.3.2 Optical Axes Long-Term Drift~~

~~The orientation of the RBS optical axes relative to the RBS mounting surface in the instrument's nominal nadir-viewing configuration shall be stable to ≤ 10 μrad (1-sigma) (TBR) over one year.~~

4.1.7 RBS Purge Fitting

The RBS shall provide a purge fitting to allow a positive dry nitrogen gas purge within the RBS during all stages of instrument and satellite integration, test, shipment, launch site processing, and while on the launch pad up to T-0.

4.1.8 RBS Thermal Control

4.1.8.1 Heaters

Heaters required for precision temperature control shall be located within the RBS, controlled by the sensor electronics and using power from the overall RBS power budget.

4.1.9 Power Requirements

4.1.9.1 Input Power

The RBS shall be designed to operate from a 28 +/- 6 Volt dc power subsystem.

4.1.9.2 Power Consumption

The RBS shall consume no more than an average orbit power of 200 watts (TBR) while in operational mode.

4.1.9.3 ~~Orbital Average and~~ Peak Power

The RBS shall not exceed a peak power requirement of 250W (TBR) for any operational mode.

4.1.10 Stray Light Constraints for RBS

The RBS shall be designed to meet its performance requirements in the presence of stray light scattered from any portion of the spacecraft outside the sensor field of view (FOV).

4.1.11 RBS Optical Surface Cleaning Access

The OLI shall provide easy access for the cleaning of all critical optical sensor surfaces during all phases of Integration and Testing (I&T). Easy access is defined as the ability to clean the optical surfaces in a single I&T shift without major sensor system disassembly or de-integration from the OLI pallet or de-integration of the OLI pallet from the S/C bus.

4.2 REFLECTIVE BAND SENSOR REQUIREMENTS

The following subsections specify the detailed coverage (FOV), spectral, spatial and radiometric measurement requirements for the RBS generated image data as well as the required formatting of the RBS data prior to transmission onto the DSAP interface.

4.2.1 Coverage

The RBS shall have a minimum field of view that provides a 177 km cross-track swath width from the NPOESS orbit.~~of 12.5° cross-track~~

4.2.1.1 Viewing Geometry

The nominal RBS viewing angle at the center of the Field Of View shall be at nadir.

4.2.1.2 Coverage

The RBS data collected for a nominal scene shall be contiguous with no gaps.

4.2.2 Spectral Bands

The RBS shall have spectral bands per the specifications in this section.

4.2.2.1 Spectral Band Widths

4.2.2.1.1 Full-Width-Half-Maximum Points

The Full-Width-Half-Maximum (FWHM) points of the relative spectral radiance response curve for each spectral band shall fall within the range of the minimum 50% lower band edge and the maximum 50% upper band edge as listed in Table 4-1.

4.2.2.1.2 Center Wavelength

The center wavelength listed in Table 4-1 for each spectral band shall be located (within the associated tolerance listed in Table 4-1) halfway between the FWHM points of the actual relative spectral radiance response curve for each spectral band.

Table 4-1. Spectral Bands and Band Widths

#	Band	Center Wavelength (nm)	Center Wavelength Tolerance (±nm)	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)	Band Heritage/ Usage
1	Coastal Aerosol	443	2	433	453	ALI/MODIS
2	Blue	482	5	450	515	ETM+ Band 1
3	Green	562	5	525	600	ETM+ Band 2
4	Red	655	5	630	680	ETM+ Band 3
5	NIR	865	5	845	885	ETM+ Band 4/ALI
6	SWIR 1	1610	10	1560	1660	ETM+ Band 5
7	SWIR 2*	2200	10	2100	2300	ETM+ Band 7
8	Panchromatic **	590	10	500	680	ETM+ Pan Band/ALI
9	Cirrus	1375	5	1360	1390	MODIS

* Minimum bandwidth is 180 nm for band 7

** Minimum bandwidth is 160 nm for the panchromatic band

4.2.2.2 Spectral Band Shape

4.2.2.2.1 Spectral Flatness

4.2.2.2.1.1 Flatness Between Band Edges

The relative spectral radiance response between the lower band edge (lowest wavelength with 0.5 of peak relative response) and the upper band edge (highest wavelength with 0.5 of peak relative response) shall have the following properties:

4.2.2.2.1.1.1 Average Response

The average relative spectral radiance response shall be greater than 0.8.

4.2.2.2.1.1.2 Minimum Response

No relative spectral radiance response shall be below 0.4.

4.2.2.2.1.2 Flatness Between 80% relative response points

The relative spectral radiance response between the minimum wavelength with a 0.8 relative response point and the maximum wavelength with a 0.8 relative response point shall always exceed 0.7.

4.2.2.2.2 Out of Band Response

4.2.2.2.2.1 Beyond 1% Relative Response

The ratio of the integrated relative spectral radiance response beyond the 1% relative response points to the integrated response between the 1% relative response points shall be less than 2%.

The 1% relative response points are the points closest to the center wavelength where the relative response first drops to 1% of the peak relative response on each side of the center wavelength. The integrated responses will be weighted by the solar exoatmospheric irradiance. Electrical crosstalk is not included within this requirement.

4.2.2.2.2.2 Response at Outer Wavelengths

4.2.2.2.2.2.1 VNIR and Cirrus

For any of the VNIR and Cirrus bands the value of the out of band relative spectral response at wavelengths which are lower than the lower band edge of the FWHM point minus 50 nm and the at wavelengths which are higher than the higher band edge of the FWHM point plus 50 nm shall not exceed 0.1% (of the normalized peak response). Electrical crosstalk is not included within this requirement.

4.2.2.2.2.2.2 SWIR

Similarly for any of the SWIR and panchromatic bands the value of the out of band relative spectral response at wavelengths which are lower than the lower band edge of the FWHM point minus 100 nm and the at wavelengths which are higher than the higher band edge of the FWHM point plus 100 nm shall not exceed 0.1% (of the normalized peak response). Electrical crosstalk is not included within this requirement.

4.2.2.3 Edge Slope

4.2.2.3.1 Wavelength Intervals – Case 1

The wavelength interval between the first 5% and the first 50% of peak relative response and the last 50% and the last 5% of peak relative response ranges shall not exceed the values in Table 4-2.

4.2.2.3.2 Wavelength Intervals – Case 2

The wavelength interval between the 1% relative response points and the corresponding 50% relative response band edge shall not exceed the values in Table 4-2.

Table 4-2. Edge Slope Intervals for RBS Bands

#	Band	Lower Edge Slope Interval 1% to 50%* (nm)	Lower Edge Slope Interval 5% to 50%* (nm)	Upper Edge Slope Interval 50% to 5%* (nm)	Upper Edge Slope Interval 50% to 1%* (nm)
1	Coastal Aerosol	15	10	10	15
2	Blue	25	20	20	25
3	Green	25	20	20	25
4	Red	25	20	15	20
5	NIR	25	20	15	20
6	SWIR 1	40	30	30	40
7	SWIR 2	50	40	40	50
8	Panchromatic	50	40	40	50
9	Cirrus	15	10	10	15

* % of peak relative spectral response for the band

4.2.2.4 Spectral Uniformity

Within a band, all detector bandwidths shall be within ±3% of the mean bandwidth. Additionally see Section 4.2.4.2.3.

4.2.2.5 Spectral Stability

Band center wavelengths and band edges shall not change by more ± 2 nm over the expected life of the mission.

4.2.2.6 Spectral Band Simultaneity

For any point within a single WRS-3 scene, the RBS shall acquire data for all spectral bands within a (2.5)-second period (TBR).

4.2.3 Spatial Data Sampling Intervals

4.2.3.1 Ground Sample Distance

4.2.3.1.1 Multispectral Ground Sample Distance

4.2.3.1.1.1 Pixel-to-Pixel Increment

RBS data shall provide a pixel-to-pixel increment, in the in-track and cross-track directions, equivalent to a Ground Sampling Distance (GSD) less than or equal to 30 m across the WRS-3 scene for RBS Spectral Bands 1, 2, 3, 4, 5, 6, 7 and 9.

4.2.3.1.2 Panchromatic Band

RBS data shall provide a single panchromatic band with a pixel-to-pixel increment, in the in-track and cross-track directions, equivalent to a GSD less than or equal to 10 m across the WRS-3 scene.

4.2.3.2 Edge Response

The mean relative edge response slope in the in-track and cross-track directions (mean of slope between 40%-60%) for RBS data shall conform to the criteria described in the following subsections.

Note: Table 4-3 lists the bands, their maximum allowable GSD, and the minimal edge slope. The edge response, in the context below, is the normalized response of the imaging system to an edge. That is, the edge response is normalized so that the mean minimum edge response is set to zero and the mean maximum response is set to 100%.

Table 4-3. GSD / Minimum Slope Specification

#	Band	Type	Maximum GSD	Slope
1	Coastal Aerosol	Standard	30 m	.027 / m
2	Blue	Standard	30 m	.027 / m
3	Green	Standard	30 m	.027 / m
4	Red	Standard	30 m	.027 / m
5	NIR	Standard	30 m	.027 / m
6	SWIR 1	Standard	30 m	.027 / m
7	SWIR 2	Standard	30 m	.027 / m
8	Panchromatic	Sharpening	10m	.081 / m
9	Cirrus	Atmospheric	30m	.027 / m

4.2.3.2.1 Standard Band Edge Response Slope

The mean relative edge response slope for RBS Spectral Bands 1, 2, 3, 4, 5, 6, 7 and 9 (<=30 m GSD) shall exceed 0.027/meter for RBS Data across the entire Field-of-View.

4.2.3.2.2 Panchromatic Band Edge Response Slope

The mean relative edge response slope for the panchromatic band, RBS spectral band 8 (<=10m GSD), shall exceed .081 / meter for RBS data across the entire Field-of-View.

4.2.3.2.3 Edge Response Overshoot

The overshoot of any edge response for all bands shall not exceed 5% for RBS data.

4.2.3.2.4 Edge Response Uniformity

The mean relative edge response slope shall not vary by more than 10% (maximum deviation from the band average) in any band across the Field-of-View and by not more than 20% (maximum deviation from the multi-band average) between RBS Spectral Bands 1,2,3,4, 5, 6, 7, and 9 for RBS data.

4.2.3.3 Aliasing

The product of the mean relative edge response slope and the GSD provided by RBS data shall be less than 1.0 for both the in-track and cross track directions.

4.2.3.4 Stray Light Rejection and Internal Scattering

The effectiveness of the rejection of stray light and internal light scattering in the RBS data is defined in terms of a scene with the following characteristics: The RBS data are collected from a circular region having a radius = 0.25 degrees and having a uniform target radiance = LT . That target region is surrounded by an annular region having an inner radius = 0.25 degrees and an outer radius = 25 degrees and having a uniform background radiance = LB.

When LB = L T, the RBS radiance measured at the center of the target region has a nominal value = LT. When LB is not equal to LT, the magnitude of the change in measured RBS radiance at the center of the target region shall be less than 0.004 times the magnitude of the difference between LB and LT. This requirement applies to all spectral bands for the duration of the nominal RBS mission for target and background radiance levels ranging from a minimum of zero to a maximum of LMax, such that LT - L B ranges from a minimum of - LMax to a maximum of L Max.

4.2.3.5 Ghosting

An extended object with a maximum diameter equivalent to an enclosing diameter of up to half the WRS-3 scene extent (88.5km) 4and , at a radiance level just below the detectors saturation level, anywhere in the RBS telescope full FOV, shall not produce a significant (as described below) "Ghost" image anywhere in the "active" detectors area of the focal-plane. This absence of a "Ghost" image requirement applies to all spectral bands in the fully populated FPA.~~Any object, at any radiance level below the detectors saturation level, anywhere in the RBS telescope full FOV, shall not produce a significant "Ghost" image (as described below) anywhere in the "active" detectors area of the focal-plane. This absence of a "Ghost" image requirement applies to all spectral bands in the fully populated FPA.~~

A "Ghost" image is a secondary image of an object, which appears as either an attenuated rendition of the original object or a blurred and attenuated version of the original object. A "Ghost" also has a constant displacement vector from the original image. A significant "Ghost" is defined as an ~~significant~~ image artifact when its peak signal after background level subtraction and radiometric calibration is above 1% (TBR) of the peak signal in the original object and above the "white" noise (random noise) level.

4.2.4 Radiometry

4.2.4.1 Absolute Radiometric Uncertainty

The RBS absolute radiometric uncertainty requirements are given in Table 4-4 for the range of Ltypical to 0.9 Lmax (Table 4-5) with all uncertainties established relative to National Institute for Standards and Technology (NIST) standards. At any other radiance across the range of 0.3 Ltypical to Ltypical the absolute uncertainty shall not exceed the values in Table 4-4 by more than 0.5%. This requirement applies to extended, spatially uniform, unpolarized targets with a known spectral shape. Uncertainty estimates include the NIST standard uncertainties.

Table 4-4. Absolute Radiometric Uncertainty Requirements

Parameter	Requirement (1-sigma)
Radiance	5%
Reflectance	3%[TBR] of actual TOA

Table 4-5. Radiance Levels for Signal-to-Noise Ratio (SNR) Requirements and Saturation Radiances

#	Band	Radiance Level for SNR, L (W/m^2 sr µm)		Saturation Radiances, L_{Max} (W/m^2 sr µm)
		Typical, $L_{Typical}$	High, L_{high}	Requirement
1	Coastal Aerosol	40	190	520~~564~~
2	Blue	40	190	545~~592~~
3	Green	30	194	510~~553~~
4	Red	22	150	433~~470~~
5	NIR	14	150	263~~285~~
6	SWIR 1	4.0	32	66.8~~72.5~~
7	SWIR 2	1.7	11	22.8~~24.7~~
8	Panchromatic	23	156	483~~524~~
9	Cirrus	6.0	N/A	83~~90~~

4.2.4.2 Radiometric Signal to Noise and Uniformity

4.2.4.2.1 Pixel Signal-to-Noise Ratios (SNRs)

The median SNRs required for all RBS data for each spectral band shall be as listed in Table 4-6.

4.2.4.2.1.1 Case 1

50% of all detectors for each band shall meet or exceed these SNR values.

4.2.4.2.1.2 Case 2

Any detector below 80% of these values shall be considered out-of-spec per section 4.2.4.7.3.

Table 4-6. SNR Requirements

#	Band	SNR Requirements	
		At $L_{Typical}$*	At L_{High}*
1	Coastal Aerosol	130	290
2	Blue	130	360
3	Green	100	390
4	Red	90	340
5	NIR	90	460
6	SWIR 1	100	540
7	SWIR 2	100	510
8	Panchromatic	80	230
9	Cirrus	50	N/A

4.2.4.2.2 RBS Data Quantization

RBS data SNR performance shall not be quantization noise limited at Ltypical and above, i.e., system noise is greater than or equal to 0.5 Digital Number. If meeting this requirement would force greater than 12 bit quantization, then quantization may be limited to 12 bits.

4.2.4.2.3 Pixel-to-Pixel Uniformity

4.2.4.2.3.1 Full Field of View

For a spatially uniform source above 2*Ltypical, the standard deviation of the calibrated values across all pixels within a line of RBS data within a band shall not exceed 0.25% of the average radiance. Temporal (within column) noise may be averaged to verify compliance with this specification.

4.2.4.2.3.2 Banding

4.2.4.2.3.2.1 Case 1

For a spatially uniform source above 2*Ltypical , the root mean square of the deviation from the average radiance across the line for any 100 contiguous pixels within a line of RBS data within a band shall not exceed 0.5% of that average radiance. Temporal (within column) noise may be averaged to verify compliance with this specification.

4.2.4.2.3.2.2 Case 2

For a uniform source above 2*Ltypical , the standard deviation of the calibrated values across any 100 contiguous pixels within a line of RBS data within a band shall not exceed 0.25% (0.5%) (TBD) of the average radiance across the line. Temporal (within column) noise may be averaged to verify compliance with this specification.

4.2.4.2.3.3 Streaking

For a spatially uniform source above 2*Ltypical, the maximum value of the streaking parameter within a line of RBS data shall not exceed 0.005 for bands 1-7 and 9 or 0.01 for the panchromatic band. Temporal (within column) noise may be averaged to verify compliance with this specification.

The streaking parameter is defined by the following equation:

$$S_i = \left| L_i - \frac{1}{2}\left(L_{i-1} + L_{i+1}\right) \right| / L_i$$

where:

L i is the calibrated radiance value measured for a pixel at an input radiance level;

Li-1 and Li+1 are similarly defined for the (i–1)th and (i+1)th pixels.

Note: These requirements apply for target radiances with spectral characteristics as follows: the spectral radiance from bare soil as observed through a dry atmosphere (excluding band 9), spectral radiance proportional to the exoatmospheric solar irradiance, and spectral radiance from a dense vegetation target as observed through a moist atmosphere (excluding band 9) (See Figure 4-1 TBD and Top of Atmosphere Radiance Values, MODTRAN 4 TBD Model table values, Section 1.5, Reference f). The target radiances are all determined using the same calibration coefficients.

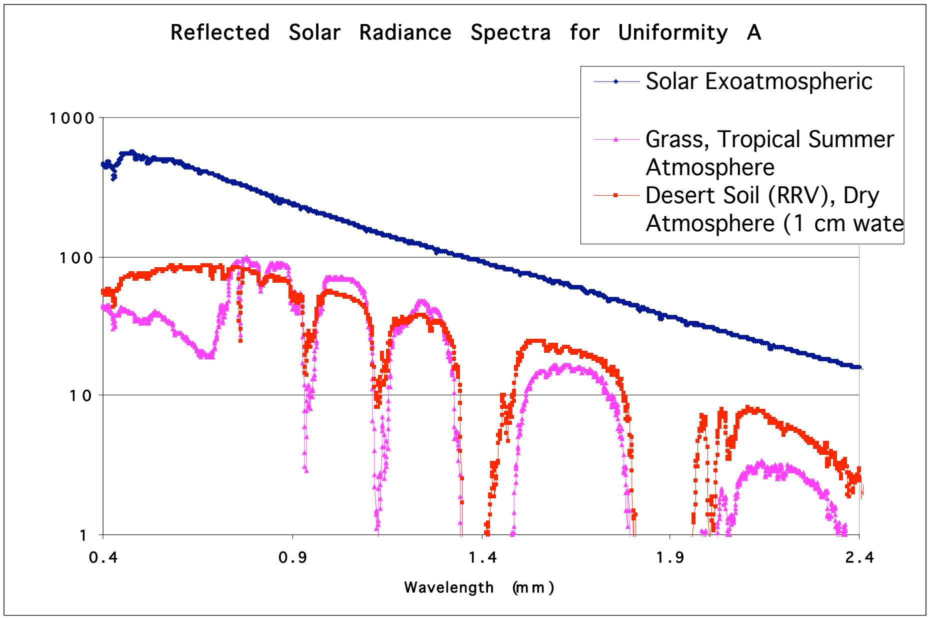


Figure 4-1. MODTRAN 4 Model Table Values

4.2.4.2.4 Coherent Noise

Any uniform scene or dark image in any band acquired by the RBS, after radiometric calibration, shall not contain coherent noise (CN) components of any frequency (f, cycles/pixel), with relative percentage amplitude DN%, that is higher than the DN%max level denoted by the following formula, DN%max(f)= 8.9936 [TBR]*f+1.9364 [TBR]. Where the DN% is given by the ratio of the individual CN component amplitude to the overall impulse-feature free Peak-to-Valley (i.e. Peak-to-Valley of the average scene background excluding any impulse noise of very high or very low pixels), and the individual CN component amplitude is the amplitude of the wave pattern generated (for example in the model of a sine wave it will be the amplitude of a sine wave defined as Asin(b+phase). This coherent noise components restriction applies to all spectral bands in the fully populated FPA, from the SCA scale shortest acquisition image to the Full FPA scale WRS-3 acquisition time.

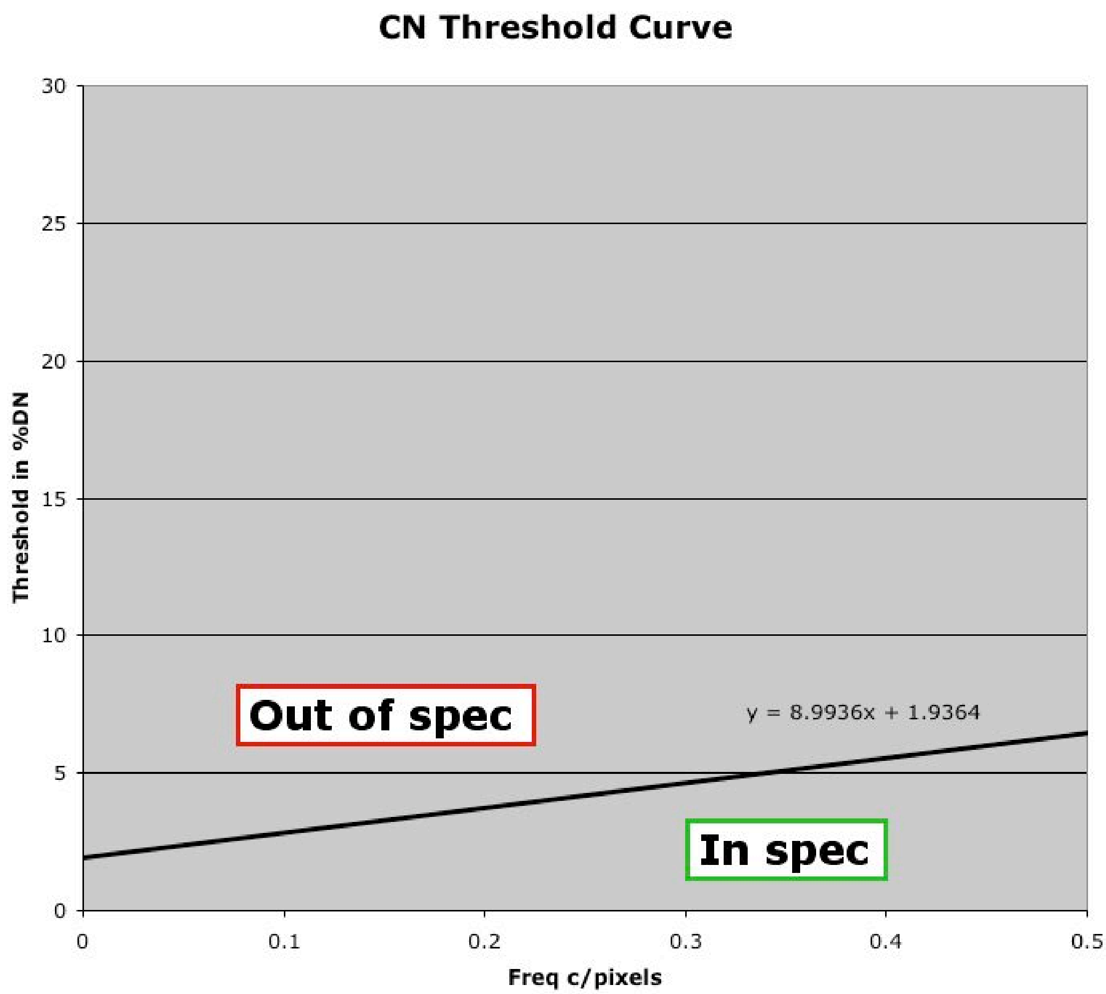


Figure 4-2. Coherent Noise Threshold Curve

Definition:
DN% = (Amplitude of Coherent component) / (impulse feature free Dynamic Range in the image)*100%

4.2.4.3 Saturation Radiances

The RBS shall detect, without saturating, signals up to the Lmax as shown in Table 4-5. Note**:** For bands 1-8, this corresponds to the radiance reflected off of a Lambertian target of 100% reflectance illuminated by the sun at a solar zenith angle of 30~~20~~°.

4.2.4.4 Polarization Sensitivity

The RBS ~~shall not exhibit~~ polarization sensitivity, as defined by the linear Polarization Factor (PF), shall be ~~of~~ less than 0.05. Note, PF = (Imax-Imin)/ (Imax+Imin).

4.2.4.5 Radiometric Stability

4.2.4.5.1 Case 1

Over any time up to 17 days after radiometric calibration, the RBS data for radiometrically constant targets with radiances greater than or equal to L-typical shall not vary by more than +/- 95% (2-sigma confidence interval) of the *sum of 1% of target radiance and the equivalent radiance of 1 bit*.

4.2.4.5.2 Case 2

Over any time period between 17 days and 7 years, after radiometric calibration, the RBS data for radiometrically constant targets with radiances greater than or equal to Ltypical shall not vary by more than plus or minus (95% or 2-sigma confidence interval) the *sum of 2% of target radiance and the equivalent radiance of 1 bit*.

4.2.4.6 Image Artifacts

4.2.4.6.1 Bright Target Recovery

The RBS data shall be such that for an image pixel that has been exposed to a radiance level of less than or equal to 1.5 times that of the saturation radiances (Table 4-5), the pixels outside the 7 x 7 region around that pixel are not altered by more than 1% of their radiance for bands 1-7 and 9 and 2% for the panchromatic band for radiances at or above Ltypical.

4.2.4.6.2 Pixel-to-Pixel Crosstalk

The RBS data shall be such that the electrical crosstalk-induced artifacts in pixels caused by regions of pixels having radiance levels less than the saturation level and which are more than ten pixels away, shall not exceed 1% of the affected pixels' radiances at or above Ltypical, after radiometric correction.

4.2.4.7 Dead, Inoperable, and Out-of-Spec Pixels

4.2.4.7.1 Dead or Inoperable Pixels

Less than 0.1% of the RBS image pixels in any WRS-3 scene shall be dead or inoperable.

Note: Dead or inoperable pixels may be removed from any performance averages and standard deviations for determining compliance to performance specifications.

4.2.4.7.2 Dead or Inoperable Pixels per Band

Less than 0.25% of the RBS image pixels in any spectral band in any WRS-3 scene shall be dead or inoperable.

4.2.4.7.3 Out-of-Spec Pixels

Less than 0.25% of the operable RBS image pixels in any spectral band in any WRS-3 scene shall fail to meet one or more performance requirements. Note: Out-of-spec pixels may be removed from any performance averages and standard deviations for determining compliance to performance specifications.

4.2.5 RBS Image and Ancillary Data Formatting Requirements

The requirements in this section dictate the output characteristics of the RBS data and the necessary ancillary data from the RBS to enable image reconstruction after transmission to the ground.

4.2.5.1 RBS Image Data Output

The RBS image data output to the DSAP shall be formatted in uncompressed CCSDS packets ~~at f~~and shall be identifiable by the packet header as to specific pixel content, time of acquisition and sequence number (per rqt 4.2.5.4)

4.2.5.2 Ancillary Data Output

The RBS shall provide to the DSAP an ancillary CCSDS data packets which provide all RBS housekeeping and ancillary data as specified in 4.2.5.3 for each full set of image frame output (one full readout of all FPAs/detectors).

4.2.5.3 Housekeeping and Ancillary Data Requirements

The RBS shall periodically (TBD) generate for inclusion in the Ancillary data output and S/C bus interfaces housekeeping and ancillary data that provides all monitored RBS temperature, voltage, current and mechanism positions as well as all RBS configuration and state information.

4.2.5.4 Output packet timing and sequencing information

Each output RBS image and ancillary packet shall be uniquely time stamped and time sequentially output using the recommended CCSDS timestamp with a precision of~~accurate to~~ 1usec (TBD).

4.2.6 In-Flight Calibration Requirements

The RBS shall have on-board calibration systems that provide sufficient data with precision and accuracy to meet the calibration and stability requirements of the RBS as described in this document.

4.2.6.1 Calibration Sources

Sources for the calibration shall include celestial objects such as the sun or moon, and on-board sources such as lamps.

4.2.6.2 Calibration Systems

The calibration systems shall at a minimum include:

1) A full aperture full system space-grade Spectralon solar diffuser with capabilities to assess the diffuser BRDF stability with time in all spectral bands and the diffuser deployment orientation stability with time. The in-flight calibration system shall maintain absolute radiometric accuracy as stated for the RBS instrument or better.

2) A lamp calibration source with redundancy that illuminates all detectors with both irradiance stabilized and current stabilized power sources. This source shall have at a minimum a total power output monitor.

3) A device by which the dark signal of the detectors can be monitored before, and after image acquisitions.

4) Dark detectors on each end of each detector array to generate enough data to track bias changes during daylight acquisitions for each band and odd/even columns (At least 16 Dark pixels per line of readout in the FPA - TBR).

5) A device by which the linearity of the RBS with respect to radiance can be characterized on orbit.

6) A source designed to be stable between prelaunch and on orbit environments and throughout launch. This source shall be exercised prelaunch and postlaunch to test the transfer to orbit stability of the RBS.

4.3 RBS RELIABILITY AND MAINTAINABILITY REQUIREMENTS

4.3.1 Lifetime Requirements

4.3.1.1 Performance Requirements

The RBS shall be designed to meet all performance requirements during and after exposure to ground test, storage, handling, and launch environmental conditions as specified in the Mission Assurance Requirements document. These environmental conditions include, but are not limited to, vibration, thermal, radiation, humidity, and pressure conditions.

4.3.1.2 Specification Compliant Operations

The RBS shall be designed to provide fully specification compliant operations for seven years after a nominal 90 day on-orbit checkout, and after characterization has been completed.

4.3.2 Single Point Failures

There shall be no credible single point failures to the RBS.

4.3.3 Reliability Requirements

The RBS shall have a reliability level of 0.90 (TBD) at the end of seven years of operations.

4.3.4 Direct Solar Illumination Detection and Protection

In all modes except OFF mode, t~~T~~he RBS shall employ a method of detecting direct solar illumination and protecting critical RBS components.

4.3.5 Direct Solar Illumination Survival

The RBS shall be capable of surviving, without permanent loss of performance, direct solar illumination for as long a period of time as required to employ protection.

4.3.6 Fault Detection and Correction

The RBS shall have an active fault detection and correction that recognizes anomalous conditions, protects and/or safes the instrument and notifies the spacecraft immediately of such conditions.

5.0 DATA STORAGE AND PLAYBACK (DSAP) SUBSYSTEM FUNCTIONAL AND PERFORMANCE SPECIFICATION

5.1 DSAP DATA INTERFACES

5.1.1 RBS Interface

The DSAP shall simultaneously ingest and store to full storage capacity uncompressed RBS CCSDS formatted image and ancillary data at the peak data rate.

5.1.2 Stored Mission Data (SMD) Downlink Interface

The DSAP shall, when playback is commanded, provide K=7 rate-_ convolutional encoded data to the SMD downlink interface at a constant data rate of 150 Mbps.

5.1.3 Direct Downlink Interface

5.1.3.1 Real-time Rate Buffer Mode

The DSAP shall, when real-time (RT) direct downlink is commanded, provide a rate-buffered output to the direct downlink transmitter interface at a constant rate of 300 Mbps.

5.1.3.2 Playback Mode

The DSAP shall, when direct downlink playback (PB) mode is commanded, provide stored data to the direct downlink transmitter interface at a selectable constant rate of 150 Mbps or 300 Mbps such that the data will be K=7 rate-_ convolutional encoded when the 150 Mbps rate is selected and unencoded when the 300 Mbps rate is selected.

5.1.3.3 Playback Coordination

The DSAP shall ~~coordinate playback operations with the NPOESS bus C&DH such~~ ensure that only complete image files are played back, either by downlink time allocation coordination or by use of a playback file start pointer~~ to ensure all image files are completely read out~~.

5.1.4 Quadrature Downlink Outputs

The DSAP shall provide synchronous quadrature ("I" and "Q") outputs for both the SMD and direct downlink interfaces, where the total DSAP output data is equally split between each quadrature output at half the total data rate.

5.2 DSAP MASS, VOLUME AND POWER INTERFACE CONSTRAINTS

5.2.1 Mass

The DSAP total mass shall be no more than 50kg (TBR). ~~The mass limit includes all required harnesses to connect the DSAP to the RBS but not any required harness to connect the DSAP to the spacecraft (S/C) bus.~~

5.2.2 Volume

The DSAP shall occupy a volume no greater than 0.5m (x) x 0.5m (y) x 0.3m (nadir - z) (TBR).

5.2.3 Operating Voltage and Current

The DSAP shall receive power from the S/C bus power supply (nominally 28±6V unregulated DC voltage).

5.2.4 Peak Load

The DSAP shall not exceed more than 300W (TBR) peak load for a duration of TBD seconds during any of its operational modes.

5.2.5 Average orbit power

The DSAP shall have a nominal average steady-state power requirement of 150 W (TBR) in normal operations, for both electronics and any required heaters.

5.3 DSAP OPERATIONAL MODES

The DSAP shall at a minimum have the following operational modes.

5.3.1 Power Off Mode

The DSAP shall have a power off mode where all DSAP functions and elements are powered down, except for survival heaters (if required). There is no requirement to retain stored image and ancillary data while the DSAP is powered off.

5.3.2 Power On

The DSAP power on mode shall provide an orderly start up and configuration of the DSAP processing, control, and memory electronics, including execution of internal diagnostics and activation of the housekeeping telemetry (TLM) interface to the S/C bus.

5.3.3 Standby Mode

The DSAP shall enter standby mode after successful completion of all diagnostic checks. While in Standby mode image data and ancillary data stored in the DSAP storage memory are retained indefinitely unless power is cycled off. Standby mode can be entered either from power on mode or from one of the other operational modes (5.3.4-5.3.8)

5.3.4 Self Test Mode

5.3.4.1 Image Data Pattern

In self-test mode, the DSAP shall generate a predetermined image data pattern that is applied to the RBS interface at the full uncompressed data rate which is then stored up to the full available capacity of the DSAP.

5.3.4.2 Playback

The DSAP shall be capable of playing back stored image or test data to either or both of the downlink output interfaces while simultaneously recording the test data.

5.3.5 Downlink Test Mode

In downlink test mode, the DSAP shall provide a pseudorandom noise (PN, PRN) pattern of 32,767 bits length (PN15, 2^{15}-1) to either or both of the downlink output interfaces for bit error rate (BER) testing of the downlink channel.

5.3.6 Image Data Ingest Mode

Image data from the RBS interface shall be stored in the file format designated in section 5.4, concurrently with playback if either or both of the downlink outputs are in operation.

5.3.7 Playback Mode

RBS file formatted image and ancillary data stored in the DSAP per requirement 5.4.2 shall be played back to either or both of the downlink interfaces based upon priorities of the stored image data.

5.3.8 Throughput Mode (Direct Downlink Mode)

The DSAP shall provide the processing and throughput capability to provide real time (RT) downlink of acquired RBS and ancillary data via the direct downlink output interface to support transmission to separate International Cooperator ground stations while at the same time playing back stored DSAP data via the SMD interface to a SafetyNet ground station.

5.3.9 Allowable Modes of Operations

Table 5-1. Allowable Simultaneous Modes of Operation

Mode	Self-Test	Downlink Test	Data Ingest	Playback	Throughput
Self-Test		YES	NO	YES	YES
Downlink Test	YES		YES	Separate modes for each downlink output	YES
Data Ingest	NO	YES		YES	YES
Playback	YES	Separate modes for each downlink output	YES		YES
Throughput	YES	YES	YES	YES	

The DSAP shall support the concurrent operation of all operational modes listed in sections 5.3.4-5.3.8 as shown in Table 5-1. (For example the DSAP could be simultaneously acquiring and storing image data from the RBS while transmitting previously stored data to a SafetyNet ground station and real time imagery to one or more International Cooperator ground station simultaneously.).

5.4 DSAP DATA STORAGE REQUIREMENTS

5.4.1 Data Storage Capacity

The DSAP shall be able to store, at end of life (EOL), the equivalent of at least 150 (TBR) WRS-3 scenes along with all necessary ancillary data required for image reconstruction of the stored scenes.

5.4.2 Data Storage File Architecture and File Access

The DSAP shall provide a file system that supports storage of the image and ancillary data as defined in the following:

5.4.2.1 RBS Image Data

The DSAP shall demultiplex RBS image data into unique image data files which contain separate and unique band sequential RBS image data formatted into CCSDS packets concatenated together into a single file of~~with the granularity of~~approximately one-quarter WRS-3 scene (TBD).
(Note: This requirement does not preclude the RBS from performing some or all of the band sequential organization and CCSDS formatting of image and ancillary data)

5.4.2.2 IDF File Header

Each file shall have an IDF file header that contains a unique identifier for the file name, a unique timestamp accurate to 1msec accuracy (TBD), along with file length, sequencing and configuration information with respect to the formatting and processing modes of the DSAP.

5.4.2.3 File Attributes

5.4.2.3.1 Assigning Attributes

The DSAP shall provide a means to assign file attributes that denote protected data, test data, and/or data that can be overwritten or deleted following playback.

5.4.2.3.2 Listing Attributes

These attributes shall also be provided when a directory listing is requested.

5.4.3 Ancillary Data Access and Handling

5.4.3.1 Ancillary Data Record Creation

The DSAP shall acquire any necessary image reconstruction and ancillary data from the spacecraft bus through the DSAP control interface and create a unique ancillary data record for each image data file store in the DSAP.

5.4.3.2 Ancillary Data Content

The ancillary data shall include information regarding spacecraft orientation, yaw steering position, timing, navigation (GPS information) as well as all instrument and DSAP telemetry housekeeping parameters (temperature, voltage, operational configuration information, mechanism states etc…).

5.4.4 Error Detection and Correction (EDAC)

The DSAP shall provide EDAC to ensure data stored on the DSAP has no more than one error in $10E^{12}$ bits prior to transfer to the either downlink interface, assuming data is stored for no more than 48 hours (TBD).

5.5 OTHER DSAP IMAGE DATA PROCESSING CAPABILITIES

5.5.1 Non-uniformity correction ~~(MOVE TO SECTION 3)~~

If ~~tThe~~the OLI ~~RBS or~~ DSAP (or RBS) performs non-uniformity correction (NUC), then the following shall apply.
~~shall be capable of performing non-uniformity correction (NUC) for each RBS detector DN value.~~

5.5.1.1 Reversible and Reconfigurable NUC Algorithm

The NUC algorithm implemented shall be fully reversible and be reconfigurable to allow for updates due to changes in detector operability.

5.5.1.2 NUC Coefficient Recording and Transmission

The OLI~~DSAP~~ shall record and transmit the NUC coefficients used with each data file.

5.5.1.3 NUC Coefficient Reception and Implementation

The OLI ~~DSAP~~ shall receive and implement updated NUC coefficient data.

5.5.2 Lossless Compression

Any data compression applied to OLI image data or ancillary data shall be lossless.

5.5.3 Aggregation

Spatial aggregation of image data shall not occur for any RBS data stored in the DSAP.

5.5.4 Encryption

The OLI shall provide any necessary encryption of data required to meet NASA or National Security requirements. (Further details TBS)

5.5.5 Direct Downlink Rate Buffering

The DSAP shall provide a rate buffer to frame-fill and/or buffer the variable rate RT image data from the RBS to a constant data rate of 300 Mbps for the direct downlink interface.

The DSAP shall be capable of sensing and correcting overflow conditions on the Direct Downlink output and recover within one IDF timeframe (see requirement 5.4.2.1)

5.5.6 Downlink Formatting

5.5.6.1 SMD Downlink

The DSAP shall perform CCSDS formatting and K-7 rate-_ convolutional coding to data played back through the SMD downlink interface output.

5.5.6.2 Direct Downlink Formatting

The DSAP shall perform CCSDS formatting and encoding for data transmitted from the direct downlink interface output, for both RT imaging and playback modes.

5.6 DATA PLAYBACK CAPABILITIES

The DSAP shall provide the following playback capabilities concurrent with data storage ingest operations.

5.6.1 Downlink File Playback Prioritization

The DSAP shall play back priority files first, followed by oldest files next, when a playback is commanded.

5.6.2 Playback Operations

5.6.2.1 Playback Requests

The DSAP shall playback requested data based upon commands received via the command and control interface.

5.6.2.2 Time Tag Priorities

The DSAP shall accept a time-range command to identify priority scenes for playback.

5.6.2.3 Downlink Time Allocation Coordination

The DSAP shall coordinate with the bus command and data handling (C&DH) system to determine time allocated for SMD playback opportunities.

5.6.2.4 Repeat Playbacks

The DSAP shall support multiple playbacks of stored data.

5.6.2.5 Directed Playbacks

The DSAP shall playback data corresponding to time tags specified in a command string at the time specified in the command string.

5.6.3 Playback Requirements

The DSAP shall be able to multiplex image and ancillary CCSDS packets into two separate physical AOS CCSDS CADU data streams.

5.6.3.1 Complete Image Data Files

The DSAP shall ensure that complete image data files are provided to the downlink interface for each separate physical AOS CADU stream when a playback command (request) is executed.

5.6.3.2 Reversible Randomization

The DSAP shall provide reversible randomization of each CADU stream to ensure that there is at least one transition (from "0" to "1" or from "1" to "0") occurs every 127 bits (PN7 randomization – TBD).

5.6.3.3 CCSDS Error Detection and Correction

The DSAP shall provide sequential ordering and CCSDS recommended error detection and correction, (RS 255,223) for each output CADU stream.

5.6.3.4 Corresponding Image and Ancillary Data

Image data and the corresponding ancillary data shall always be output together.

5.6.4 Null or fill data generation

The DSAP shall insert fill CADUs and fill packets as required to maintain a synchronous, constant data rate output to the spacecraft downlink interface.

5.6.5 Automatic File deletion

The DSAP shall automatically delete or allow overwriting of any image data files designated for overwrite after the image data file has been transferred to the DSAP downlink output interface.

5.6.6 File data overwrite protection

The DSAP shall allow commands to designate any single or set of image data file as protected which would disable the automated file deletion feature.

5.6.7 DSAP File Directory Listing

The DSAP shall, on command, provide a listing or directory of its file system including key file attributes, to be transferred as a separate CCSDS packet type via the wideband interface and/or may be also transferred through the DSAP control interface via the S/C telemetry path to the ground.

5.7 DSAP RELIABILITY REQUIREMENTS

The DSAP shall have a reliability level of 0.90 (TBD) at the end of seven years of operations.

5.7.1 Single Point of Failure

The DSAP shall have no credible single point failures.

5.7.2 Fault Detection and Correction

The DSAP shall have autonomous internal fault detection and correction capabilities to provide notification of anomalous operating conditions through the command and control interface.

5.7.3 Graceful Degradation

The DSAP shall be designed for graceful degradation of data storage capacity in the event of failed memory functions, with no more than 5% (TBD) of DSAP data storage capacity being affected by any failed memory board or memory board component per failure.

5.8 LIFETIME REQUIREMENTS

5.8.1 Performance Requirements

The DSAP shall be designed to meet all performance requirements after exposure to ground test, storage, handling, and launch environmental conditions, and during exposure to all environmental conditions as specified in the Mission Assurance Requirements~~Test Requirements Document~~, including, but not limited to, vibration, thermal, radiation, humidity, and pressure conditions.

5.8.2 Specification Compliant Operations

The DSAP shall be designed to provide fully specification-compliant operations for seven years after on-orbit after initial checkout and characterization has been completed.

6.0 OLI SIMULATOR AND GSE REQUIREMENTS

This specification establishes the functional and performance requirements for the Ground Support Equipment (GSE) to be used for verification of the Operational Land Imager (OLI) instrument. The GSE comprises the unique equipment required to operate, handle, test, and calibrate the OLI at the contractor's facility and at the spacecraft integrator's facility.

The OLI GSE shall consist of the following:

a. System test equipment (STE)
b. Calibration test equipment (CTE)
c. Handling fixtures
d. Test fixtures
e. Shipping / storage containers

6.1 SYSTEM TEST EQUIPMENT (STE)

6.1.1 OLI Operation

The System Test Equipment (STE) shall comprise the hardware, software, and cabling and be used to operate the OLI during performance verification and calibration testing by both by the instrument manufacturer and by the spacecraft integrator at their respective facilities and at the launch facility.

6.1.2 Interfaces

The STE shall provide all possible interfaces, e.g., power, clock, command, and telemetry.

6.1.3 Capabilities

The STE shall be capable of recording, displaying, distributing, and analyzing the data received from the OLI and ground support equipment including all instrument test points.

6.1.4 Data Capture and Record

The STE shall be capable of real-time data capture and recording all data as received from the OLI and GSE

6.1.5 Dynamic Display

The STE shall be capable of real-time dynamic data display.

6.1.6 Hard Copy

The STE shall have the capability of generating hard copy print out of all analysis results, screen dumps, and processed data.

6.1.7 Hard Media

The STE shall have the capability of generating and receiving hard media (e.g., Tape, DVD).

6.1.8 Signal and Power Inputs

The STE shall furnish all power, timing signals, and commands needed by the OLI and normally supplied by the spacecraft.

6.1.8.1 Power Line Isolation

All power lines shall be physically isolated from signal lines, i.e., by shielded and separate cables.

6.1.8.2 Short Circuit and Voltage Transient Protection

The power supplies shall have short-circuit protection and voltage-transient protection.

6.1.9 Processing Capabilities

The STE capabilities shall include:

a. Performing a self-test
b. Sending commands to the instrument
c. Controlling the simulated S/C interfaces and external calibration GSE
d. Receiving data from the OLI, GSE, and test chamber
e. Performing health and safety checks to guarantee the safety of the instrument (in all states)
f. Analyzing the data in real-time and in an off-line mode

6.1.9.1 Timeliness

The STE shall be capable of timely, within 2 hours (TBR), data analysis / processing during testing.

6.1.9.2 Trending and Sensor Data Analysis Software

The STE shall include engineering and instrument data trending capability and sensor data analysis tools to determine the performance characteristics of the instrument.

6.1.9.3 Previously Captured Data

The STE shall simultaneously operate and monitor the instrument and perform data analysis.

6.1.10 Display

The STE shall display instrument engineering data as well as external GSE data.

6.1.10.1 Information Selection

The STE shall have the capability of selecting information to be displayed from a set of pre-stored display templates.

6.1.10.2 SI Units

The STE shall have the capability of displaying test data in SI Units as well as raw digital numbers.

6.1.10.3 Operator Interface

The STE shall have an operator interface.

6.1.11 STE Interface to CTE

The STE shall provide an interface with the OLI CTE so that data will be entered into the automated data system and correlated (TBR).

6.1.12 Power

The STE shall operate from a 115-volt, 60-Hertz (Hz) line.

6.1.13 Limits Program

The STE shall have the capability of monitoring all command states, selected voltages, currents, temperatures, and other telemetered and derived parameters of the OLI and ancillary GSE telemetry in real-time.

6.1.13.1 Critical Function Monitoring

Critical Functions shall be monitored.

6.1.13.2 Critical Fault Handling

The STE shall alarm if a critical fault occurs and will automatically protect the instrument if appropriate operator action is not taken.

6.1.13.3 Operational Mode Verification

The STE shall be designed to verify all operational modes of the OLI and record and alert the operator of any out-of-tolerance items as they occur.

6.1.13.4 Automatic Sequence Bypass

All automatic sequences resident in the instrument or in the STE shall be capable of being bypassed by commands.

6.1.13.5 Program Operational Availability

At the first application of power during instrument integration and continuing through all periods of operation and/or test, the limits check program shall be operational.

6.1.13.6 Command and Operational Time Log

The STE shall maintain a command and operational time log.

6.2 CALIBRATION TEST EQUIPMENT (CTE)

6.2.1 Instrument Characterization / Calibration

Calibration Test Equipment (CTE) shall provide the capability to fully characterize and calibrate the instrument.

6.2.2 Availability for Spacecraft Level Tests

A sufficient set of CTE shall be provided for use at the spacecraft contractor's facility for all spacecraft-level tests.

6.3 HANDLING FIXTURES

Handling fixtures shall have the capability of moving the OLI, removing the OLI from and returning it to the shipping/storage container, and for integration of the OLI onto the spacecraft.

6.4 TEST FIXTURES

Test fixtures shall be provided to support performance verification, environmental testing and calibration of OLI.

6.5 SHIPPING / STORAGE CONTAINERS

The OLI shipping & Storage Containers shall be reusable, water-resistant, and airtight with filtered pressure control system.

6.5.1 Purge

The containers shall incorporate means of purging with dry nitrogen or dry air.

6.5.2 Temperature, Humidity, Shock and Pressure Monitors

6.5.2.1 Container Measurements

The containers shall incorporate means of measuring and recording shocks, temperature and humidity within the container.

6.5.2.2 External Container Indicators

Temperature, humidity, and pressure monitors shall have external indicators on the outside of the containers.

6.5.3 Airtight Conditions

6.5.3.1 Duration

Containers shall maintain airtight conditions for over 3 (TBR) weeks with an internal pressure greater than 1.05 atm.

6.5.3.2 Airlifting

Containers shall be capable of being airlifted without loss of internal pressure.

6.5.4 Other GSE

For all other GSE, reusable storage/shipping containers shall be provided.

6.5.5 Use in Clean Room

All containers shall be suitable for use in the clean room, after a minimal amount of cleaning.

6.6 ENVIRONMENTAL CONDITIONS

6.6.1 General Conditions

GSE shall generally be subject to controlled environments typical of instrument manufacturer test and integration facilities.

~~6.6.2 Electromagnetic Interference~~

~~The GSE shall not generate electromagnetic interference (EMI) that would interfere with the instrument or that would prevent the instrument from meeting the EMI requirements.~~

6.7 TRANSPORTABILITY

GSE shall be designed to facilitate mobility within test and integration facilities of the instrument manufacturer.

6.8 MARKING

All GSE assemblies shall be marked with the assembly name, part number, and connector reference designations.

6.8.1 Rollover Fixture Bolts

Rollover fixture bolts shall remain in place at all times while instrument is attached.

7.0 OLI PROCESSOR(S), SOFTWARE AND COMMAND AND DATA HANDLING REQUIREMENTS

7.1 ON-BOARD PROCESSORS (OBP)

On-Board Processors refers to the CPU, RAM, ROM, NV-RAM, clocks, and component interface and monitor circuitry such as temperature, voltage, and current sensors.

7.1.1 OBP Radiation Immunity

The OBP(s) shall be sufficiently radiation immune/tolerant and redundant to support mission lifetime requirements.

7.1.2 SEUs

The OBP(s) shall be protected against SEUs and other memory and processor errors through the use of design features such as radiation hardened parts, memory error detection and correction (EDAC), periodic software refresh of critical hardware registers, processor and register majority voting, watchdog timers, etc.

7.1.3 Flight Load Non-volatile Memory

The OBP shall possess sufficient non-volatile memory to contain the entire flight software image at launch.

7.1.4 Flight Processor Resource Sizing

During development, flight processors providing computing resources for OLI subsystems shall be sized for worst case utilization not to exceed the capacity shown below (measured as a percentage of total available resource capacity):

Table 7-1. Flight Processor Resource Sizing

Resource/Phase	S/W PDR	S/W CDR	S/W AR
RAM Memory	40%	50%	60%
EEPROM Memory	30%	40%	50%
CPU	30%	40%	50%
I/O Bandwidth	30%	40%	50%
Bus Utilization	30%	40%	50%

7.1.4.1 Resource Utilization Monitors

The flight software shall provide the capability to monitor the resource utilization by software subsystems or critical functions.

7.1.4.2 Downlink in Telemetry

The resource utilization monitors shall be available for downlink in telemetry.

7.1.5 Watchdog Timer

The OBP shall provide a watchdog timer that can cause a hardware reset to the OBP.

7.1.5.1 Watchdog Timer Enable/Disable

The OBP watchdog timer shall be capable of being enabled and disabled by a hardware ground command.

7.1.5.2 Watchdog Timer Update

The flight software shall update the watchdog timer at a TBS rate when all critical software functions are executing nominally.

7.1.6 Reset Hardware Command

The OBP shall be capable of being reset via hardware command

7.1.7 Reset/Reboot/Reinitialization Self-test

The OBP shall be capable of performing an autonomous self-test of the OBP hardware (processor, bus, memory, etc.) upon hardware reset or initial power-on.

7.1.8 On-orbit Reprogrammability without OBP Restart/Reboot

The OBP(s) shall be reprogrammable on-orbit to allow for new versions of software segments and table values to be loaded from the ground without computer restart.

7.1.9 High Speed Test Access Port

The OBP shall include a built-in test access port, allowing high-speed loading and dumping of processor memory to support pre-launch testing.

7.1.10 OBP Clock Accuracy

The OBP clock shall provide sufficient resolution and stability to meet all flight software timing requirements.

7.1.11 OBP Timing Interface

The OBP shall be able to correlate all data and execute time-tagged commands relative to GPS time standard.

7.2 REDUNDANCY MANAGEMENT

The instrument shall have the ability to autonomously perform reconfiguration of redundant components as required to enter into a safe mode.

7.2.1 Redundant Component Status

7.2.1.1 Redundant Monitors Telemetry

The status of all redundant components shall be telemetered to the ground.

7.2.1.2 Ground Override of Component Status

The OBP shall allow the effective status of any redundant component to be settable by ground command.

7.2.1.3 Retention of Redundant Component Status

The OBP and associated flight software shall provide a means by which the OBP retains knowledge of the status of redundant components following processor restart, processor failover, RAM memory loss, or bus under-voltage so that the instrument avoids switching to previously failed components.

7.2.1.4 Component Status Determination

The flight software shall interrogate and determine the status of instrument components.

7.2.2 Redundant Component Configuration

7.2.2.1 Autonomous Component Switch

The OBP shall not autonomously switch control to a failed redundant component.

7.2.2.2 Commandability of Redundant Component Configuration

The operational configuration of OBP redundant components (e.g., processor, Instrument bus, memory, non-volatile memory, etc.) shall be commandable and configurable from the ground.

7.2.2.3 Retention of Instrument Configuration

The OBP shall provide a means to retain knowledge of the correct instrument configuration (i.e., which of the redundant components is to be used as the active component) through events such as bus undervoltage, processor reboots, and processor switchovers.

7.2.2.4 Autonomous Reconfiguration Limit

Autonomous reconfigurations shall not be required for normal operations of the instrument or its components.

7.2.2.5 Ground Override of Autonomous Anomaly Responses

All flight software autonomous functions, automatic safing, or switchover capabilities shall be capable of being separately disabled, enabled, executed, or over-ridden, or aborted by ground command.

7.2.2.6 Reconfiguration Notification

All autonomous equipment reconfigurations initiated by the flight software shall be reported in normal telemetry, and shall generate a critical event message.

7.3 FLIGHT SOFTWARE

7.3.1 General Requirements

All flight software (including firmware) programs and data for the OBP shall meet the requirements in this section.

7.3.2 Software Module Upload

The flight software shall be capable of being uploaded in modules, units, segments, or objects.

7.3.3 Flexibility and Ease of Software Modification

The OLI flight software design shall be flexible and table-driven for ease of operation and modification. It shall be rigid in terms of scheduling and prioritization of critical processing tasks to ensure their timely completion. Limits and triggers for anomaly responses shall be readily accessible and changeable by ground command.

7.3.3.1 Tables

All OLI flight software data that are anticipated to be modified or examined by ground operators shall be organized into tables.

7.3.3.1.1 Table Locations

The flight software shall have knowledge of the location of each table such that ground operators need only reference a table number (for the entire table), or a table number and position within the table (for a partial table).

7.3.3.1.2 Physical Memory Locations

The flight software shall internally maintain table physical memory locations such that the ground can load and dump tables without the knowledge of where the data resides in physical memory, and no ground software or database change shall be required when the data is relocated due to a recompilation of the flight software.

7.3.3.2 Command Definition Independent from Processor Physical Memory Locations

The definition of OLI commands within the ground database shall not be dependent on physical memory addresses within the flight software.

7.3.3.2.1 No Usage of Uploaded Physical Addresses

All commands processed by the flight software (with the exception of 7.4.13) shall be interpreted by the flight software without the use of any uploaded physical address.

7.3.3.2.2 Command Definitions Unaffected by Recompiling

Existing command definitions in the database shall be unaffected when the flight software is recompiled.

7.3.4 Responsiveness to Ground Originated Changes

The OLI flight software design shall accommodate processing of ground commands, on-orbit revisions to software and telemetry formats, and computer self checks.

7.3.5 Software Event Logging in Telemetry

The OLI flight software shall include time-tagged event logging in telemetry. The event messages shall capture all anomalous events, and important system performance events.

7.3.6 Software Version Number

The flight software shall store the version of the software onboard.

7.3.6.1 Retrievability

The flight software version number shall be retrievable (either in telemetry or table dump).

7.3.6.2 Version Number Modifications

The flight software version number shall be modified whenever the software was modified.

7.3.6.3 Event Message Filter

The flight software shall provide a means to filter (discard) individual event messages.

7.3.6.4 Event Counters

The flight software shall maintain counters for the total number of event messages generated, for the number of event messages discarded because of queue overflow, and for the number of event messages discarded by filters.

7.3.7 Initialization

The flight software shall provide for separate Cold Restart and Warm Restart initialization processing.

7.3.7.1 Cold Restart Initialization

The flight software shall execute the Cold Restart initialization processing when starting execution from a hardware reset.

7.3.7.1.1 Cold Restart Initialization Execution Steps

The Cold Restart initialization shall execute from non-volatile memory, shall reset the command counter, and shall restore default telemetry contents.

7.3.7.1.2 Flight Software Configuration

The Cold Restart initialization shall place the flight software in a safe, known, deterministic configuration.

7.3.7.2 Warm Restart Initialization

The flight software shall execute the Warm Restart initialization processing when restarting the flight software from software command.

7.3.7.2.1 Preservation of Statistics, Memory Tables, and Command Sequences

The Warm Restart Initialization shall preserve command processing statistics, and shall preserve memory tables and command sequences that were previously uploaded.

7.3.7.2.2 Avoidance of Warm Restart Loops

When the Warm Restart count equals or exceeds a predetermined value, the flight software shall affect a Cold Restart in lieu of the Warm Restart.

7.4 FAILURE DETECTION AND CORRECTION (FDC)

The flight software shall continuously monitor instrument health and safety data and, in the event of an anomaly, safely configure the instrument and report the anomaly to the ground in telemetry.

7.4.1 Critical OBP Function Protection

The OBP shall protect critical functions from temporary or permanent faults or errors within all processors, including protection against such failure modes as infinite software loops, race conditions, and bus under-voltage conditions.

7.4.2 OBP Health and Safety Monitoring

The OBP shall continuously monitor its health and safety and report the result of its health and safety checks to the ground in spacecraft telemetry.

7.4.3 Failsafe Recovery Mode

The flight software shall provide a failsafe recovery mode that depends on a minimal hardware configuration with all interrupts disabled and is capable of accepting and processing a minimal command subset that is sufficient to load memory and begin execution at a specified memory address.

7.4.4 Flight Software Monitors

The flight software shall provide a table driven means for verifying proper execution of critical software tasks or functions, and perform a corrective action in the event that one or more of the critical tasks fails to meet performance requirements.

7.4.5 Health and Safety Monitor Table

The flight software shall provide a table driven mechanism for defining anomalous conditions and the corrective action(s) to be performed in response for each condition.

7.4.6 Health and Safety Monitor Table Entries

The anomalous conditions defined in the Health and Safety Monitor table shall include software generated event messages, component status data, and all subsystem, software, and housekeeping data.

7.4.7 Monitor Table Actions

The actions defined in the Health and Safety Monitor Tables shall include execution of one or more stored command sequences.

7.4.8 Ground Control of Health and Safety Monitor Table

The Health and Safety Monitor table as a whole, and single entries within the table, shall be enabled, disabled, loaded and dumped by ground command.

7.4.9 Memory Table Verification

The flight software shall implement tables in memory such that individual segments of tables can be verified, and reloaded from the ground.

7.4.10 Memory Location Load and Dump Capability

The flight software, and associated on-board computer hardware, shall provide the capability to load & dump any location of on-board memory to the ground upon command by referencing its physical memory address.

7.4.11 Segment, Module, and Object Upload and Dump

The OBP shall support the upload and dumping of flight software in segments, modules, tables, or objects.

7.4.12 Memory Dumps During Normal Operations

The flight software memory dump capability shall not disturb normal operations.

7.4.13 Memory Dwell

The flight software shall provide a mechanism to telemeter the contents of selected addresses in memory to support debugging efforts and provide additional telemetry points which may have been unanticipated at development time.

7.4.14 Dwell Tables

The memory dwell function shall have the ability to sample selected memory addresses at rates exceeding the rate at which the dwell data is reported in the telemetry stream.

7.4.15 Dwell Table Control

The dwell table and each entry within the table shall be capable of being enabled, disabled, loaded, or dumped via ground command.

7.5 COMMAND AND DATA HANDLING (C&DH)

All processor hardware for the OLI and its functional subsystems shall meet the requirements of the NPOESS GIID and all requirements for interfacing with the MIL-STD-1553B (per the NPOESS reference) if applicable.

Note: The actual hardware architecture for interfacing OLI and its subsystems to the NPOESS spacecraft bus are left within the design space of the OLI contractor but must comply with all NPOESS GIID requirements.

7.5.1 Stored Commands

The OBP flight software shall provide three types of stored commanding: stored time-tagged single commands, stored absolute-time command sequences, and stored relative-time command sequences.

7.5.1.1 Stored Time-tagged Single Commands

The C&DH shall provide the capability to store time-tagged single commands, and execute those commands at the absolute time identified in the command's time-tag.

7.5.1.1.1 Stored Commands Dump

The C&DH shall provide a mechanism to read out the time-tagged contents of the command storage buffers.

7.5.1.1.2 Stored Command Modifications

Stored commands shall be modifiable by ground command, including the addition and deletion of time-tagged commands.

7.5.1.1.3 Telemeter ID on Execution

A command identifier shall be telemetered upon execution of each stored command.

7.5.1.1.4 Command Schedule Uplink

The stored command schedule shall be selectable, interruptible, and uplinkable via ground command.

7.5.1.1.5 Stored Command Timing Accuracy

The resolution of the least significant bit of the specified time shall be one second.

7.5.1.1.6 Stored Command Transmission

The flight software shall send stored commands within 0.1 seconds of the requested time.

7.5.1.2 Stored Command Sequences

The C&DH shall provide both absolute-time stored command sequences and relative-time stored command sequences. All requirements in this section apply to both types of stored command sequences.

7.5.1.2.1 Stored Sequence Modifications

The absolute-time and relative-time stored command sequences shall be stored in onboard RAM, and be modifiable by ground command including the addition and deletion of separate command sequences.

7.5.1.2.2 Command Sequence Table Dumps

The absolute-time and relative-time stored command sequence capability shall be designed so that each stored command sequence table can be dumped to the ground by a single, simple command and not by an elaborate memory dump procedure.

7.5.1.2.3 Sequence Identification

Each absolute-time and relative-time stored command sequence shall have a unique identifying name or number.

7.5.1.2.4 Sequence Thread Identification

The C&DH shall use the unique command sequence identifiers to report the status of each actively executing command sequence in telemetry.

7.5.1.2.5 Stored Sequence Control

Individual absolute-time and relative-time command sequences shall be enabled, disabled, paused, or cancelled by ground command.

7.5.1.2.6 Command Validation

Absolute-time and relative-time stored commands shall be validated like other commands, with any command sequence whose command has failed validation suspending execution and reporting the problem in telemetry.

7.5.1.2.7 Command Sequence Reports in Telemetry

There shall be indicators in normal telemetry reporting all of the absolute-time and relative-time stored command sequences that are currently active, with each command executed from a stored sequence also being reported in normal telemetry.

7.5.1.2.8 Scheduled Sequences Reported in Telemetry

A time-ordered preview of pending absolute-time commands and pending relative-time commands in active stored command sequences shall be reported in telemetry.

7.5.1.2.9 Sequence Activation

The C&DH shall provide for absolute-time stored command sequences and relative-time stored command sequences to be activated by a simple command that references the identifying name or number of the command sequence.

7.5.1.2.10 Activation by Stored Command

Real time and stored single commands shall have the ability to invoke absolute-time stored command sequences and relative-time stored command sequences.

7.5.1.2.11 Stored Command Sequence Capacity

The number of absolute-time and relative-time stored command sequences and maximum size of any particular stored command sequence shall be limited only by the size of the Command Sequence Storage Table.

7.5.1.2.12 Stored Command Timing Accuracy

The resolution of the least significant bit of the specified time shall be one second.

7.5.1.2.13 Stored Command Transmission Time

The flight software shall send stored commands within 0.1 seconds of the requested time.

7.5.1.2.14 Late Commands

In the event that current time is past the execution time for any stored command, then the corresponding command sequence shall suspend execution and report the problem in telemetry

7.5.1.3 Absolute-time Stored Command Sequences

The C&DH shall provide the capability to store multiple sequences of absolute-time time-tagged commands, and to execute those commands at the absolute time identified in the time-tag associated with each command in the sequence.

7.5.1.3.1 Concurrent Absolute-time Command Sequence Execution

The C&DH shall have the ability to execute TBS (multiple) absolute-time stored command sequences concurrently.

7.5.1.3.2 Absolute-time Command Time-Tags

Each command of an absolute-time stored command sequence shall have a time-tag that references a fixed absolute time.

7.5.1.4 Relative-time Stored Command Sequences

The C&DH shall provide the capability to store multiple sequences of relative-time time-tagged commands, and to execute those commands at the time identified in the time-tag associated with each command in the sequence (see section 7.5.1.4.2).

7.5.1.4.1 Concurrent Command Sequence Execution

The C&DH shall have the ability to execute TBS (multiple) absolute-time stored command sequences concurrently.

7.5.1.4.2 Relative-time Command Time-Tags

Each command of a relative-time stored command sequence shall have a time-tag that specifies a variable delta time interval relative to the time that the previous command in the sequence was executed. The first command of a relative-time command sequence can have a relative-time of zero to indicate that it is to be executed immediately upon sequence activation.

7.5.1.4.3 Nested Sequence Activation

Relative-time stored command sequences shall be capable of invoking other relative-time stored command sequences, but not themselves directly.

7.5.1.4.4 Sequence Activation Loops

The C&DH shall report command sequence activation chains in telemetry for the ground system to alert operators when a command sequence execution thread is in a sequence activation loop.

7.5.1.4.5 Re-entrant Command Sequences

The C&DH shall be capable of executing any relative-time stored command sequence within the context of multiple different active sequences concurrently.

7.5.1.4.6 Sequence Nesting Depth

The C&DH shall provide the capability for command sequences to nest up to 8 levels deep.

7.5.2 Schedule Management

One or more daily schedules, i.e. Absolute Time Sequence (ATS), are created and maintained by the ground system for instrument operations. These schedules will be stored on-board the OLI and executed by the flight software. The flight software shall provide the capability for ground system to select the schedule to be run, or to switch to a different schedule, or to modify a schedule and switch to a modified schedule.

7.5.2.1 Stored Command Capacity

The flight software shall provide the capacity to store command sequences to provide a minimum of two full 48-hour instrument schedules.

7.5.3 Command Processing

7.5.3.1 Command Sources

The C&DH command processor shall provide four (4) different command modes: real-time single commands, stored time-tagged single commands, stored absolute-time command sequences, and stored relative-time command sequences. Stored commands are defined in the previous section.

7.5.3.2 Concurrent Command Functions

The C&DH shall be capable of processing real-time commands while concurrently executing long-duration commands such as on-board processor uploads.

7.5.3.2.1 Command Source Priority

When commands from more than one source are ready to be executed at the same time, all of the ready commands shall be executed in sequence according to a command source priority. Real-time single commands first, stored time-tagged single commands next, then stored absolute time sequence commands, then stored relative time sequence commands. When more than one command sequence of the same type (e.g. two relative time sequences) have a command ready to execute at the same time, the commands shall be executed in TBD sequence.

7.5.3.3 Common Command Requirements

The requirements listed in this section and subsections apply to all commands regardless of source.

7.5.3.3.1 Command Verification

All commands shall be verified by changes in telemetry data.

7.5.3.3.2 Command Rejection Indication

The command system shall provide an indication of command rejection.

7.5.3.3.3 Command Termination

Any on-going command execution shall be capable of immediate termination.

7.5.3.3.4 Command Buffer Reset by Ground

All command storage buffers shall be capable of ground-initiated reset or clear.

7.5.3.3.5 Command Lockout

There shall be no command lockout.

7.5.3.3.6 Command Data Tables

Commands shall be capable of accessing information from one or more separate data tables stored in onboard RAM.

7.5.3.3.7 Parameter Table Load

The C&DH shall provide the capability to load a parameter of a table without loading the entire table.

7.5.3.4 Real-time Single Commands

Real-time single commands shall execute immediately following verification of proper receipt from the spacecraft.

7.5.3.4.1 Command Execution Sequence

The C&DH shall implement an instrument/ground mechanism to prevent command execution out of sequence.

7.5.3.4.2 Command Counter

The C&DH shall implement a command protocol to account (preferably via command count) for all real-time commands accepted by the instrument for execution.

7.5.3.4.3 Single Function Commands

Each real-time command shall perform only one function, fully identified in the command data field. For example toggle commands would not be permitted as they do not fully define the final state.

7.5.4 Telemetry Parameters

OLI shall provide sufficient spacecraft telemetry to ensure proper control and monitoring of OLI health and safety, and to identify anomalous conditions.

7.5.4.1 Parameter Resolution

Each individual data channel shall be sampled at a rate sufficient to resolve parametric changes in the data being measured.

7.5.4.1.1 User Defined Telemetry

The C&DH shall provide the capability to accept uploaded ground-defined telemetry stream definitions consisting of any combination of parameters and sample rates.

7.5.4.1.2 Telemetry Definitions Storage

The C&DH shall provide onboard storage for TBD different User Defined telemetry streams.

7.5.4.1.3 Telemetry Stream Activation

The C&DH shall provide the capability to select a telemetry stream definition from onboard storage via a single ground command.

7.5.4.1.4 Telemetry Channel Capacity

Transmission of memory and table dumps; special telemetry streams, or user-defined telemetry streams shall not preclude the transmission of the normal telemetry stream.